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CORRIGENDUM

The term "Aeroboost" has been incorrectly used to describe the half-cylindrical corner fairings tested on the IHC 1600 straight truck referred to in the following feature article from the DME/NAE Quarterly Bulletin No. 1976(3).

A Wind Tunnel Investigation into the Fuel Savings
Available from the Aerodynamic Drag Reduction of Trucks

The half-cylindrical fairings were assumed to represent the AeroBoost I which has a non-circular cross-section. According to the manufacturer, the non-circular section provides better performance than the simpler device tested. No tests were performed on the AeroBoost III, a deflector designed for use on combination vehicles.

Kevin R. Cooper

March 1, 1977 Kevin R. Cooper

FOREWORD

The Quarterly Bulletin is designed primarily for the information of Canadian industry, Universities, and Government Departments and agencies. It provides a regular review of the interests and current activities of two Divisions of the National Research Council of Canada:

The Division of Mechanical Engineering
The National Aeronautical Establishment

Some of the work of the two Divisions comprises classified projects that may not be freely reported and contractual projects of limited general interest. Other work, not generally reported herein, includes calibrations, routine analysis and the testing of proprietary products.

Comments or enquiries relating to any matter published in this Bulletin should be addressed to: *DME/NAE Bulletin, National Research Council of Canada, Ottawa, Ontario, K1A 0R6*, mentioning the number of the Bulletin.

AVANT-PROPOS

Le Bulletin Trimestriel est conçu en premier lieu pour l'information de l'Industrie Canadienne, des Universités, des Agences et des Départements Gouvernementaux. Il fournit une revue régulière des intérêts et des activités actuelles aux quels se consacrent deux Divisions du Conseil National de Recherches du Canada:

Division de Génie Mécanique
Etablissement Aéronautique National

Quelques uns des travaux des deux Divisions comprennent des projets classifiés qu'on ne peut pas rapporter librement et des projets contractuels d'un intérêt général limité. D'autres travaux, non rapportés ci-après dans l'ensemble, incluent des étalonnages, des analyses de routine, et l'essai de produits de spécialité.

Veuillez adresser tout commentaire et toute question ayant rapport à un sujet quelconque publié dans ce Bulletin à: *DME/NAE Bulletin, Conseil National de Recherches du Canada, Ottawa, Ontario, K1A 0R6*, en faisant mention du numéro du Bulletin.

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RAILWAY SWITCH PROTECTION BY A HIGH VELOCITY AIR CURTAIN†

T.R. Ringer

Low Temperature Laboratory

Division of Mechanical Engineering

C.J. Dalton

Canadian National Railways

Montreal, Quebec

SUMMARY

The background leading to the development of the "Horizontal Air Curtain Switch Protector" is outlined. A comparison of the energy necessary to protect a switch from snowfall and that required to melt and/or vaporize snow with a switch heater is discussed. The laboratory tests and the field tests on the first experimental air curtain in Ottawa and Montreal were sufficiently encouraging to extend the field tests. Following the second winter of field trials a more advanced design air curtain protector was installed in the CN Montreal classification yard. At the conclusion of the third winter of tests a decision was made by the CN to install ten units across the system for a more extensive evaluation of this switch protection system under different climatic conditions. The results from the field tests during the winter of 1975-76 are presented and some changes proposed as a result of this experience are outlined. This protection method offers economic advantages in terms of capital cost, energy operating cost and maintenance.

INTRODUCTION

One of the evolutionary changes taking place in the railway is gradual replacement of the manual cleaning of snow from track switches. The failure of switches from snow build-up has been well known for a century and a variety of equipment has been developed to overcome this problem. Most cures have been based on the application of heat and it was because of difficulties encountered with the thermal equipment that the National Research Council became involved in this field.

Starting in 1969 test programs on switch heaters, either of existing or new designs, were conducted under simulated conditions in a large cold chamber of the Low Temperature Laboratory at Ottawa. In a 50-foot long cold chamber full size switches, either #12 or #20 turnouts, were installed for heater tests. The cold chamber can be cooled to approximately −65°C (−85°F), which is much lower than that required for testing switches in snowfall. Wind velocities up to 40 mph can be generated with portable fans while snowfall rates exceeding 3 inches per hour can be produced. In the investigation on the thermal protection of track switches a test standard of 0°F, 20 mph and 1 inch of snow per hour was utilized.

The results of the cold chamber tests showed that a thermal protection system required at least 250,000 Btu per hour to protect a 22-foot track switch (a #12) under the specified test conditions. Moreover, it was shown that this amount of heat needed to be properly distributed to the critical areas of the switch and that the most satisfactory way of accomplishing this was with forced convection and a set of ducts and nozzles.

Since 1969 a considerable amount of effort has been expended by the railways, the suppliers and NRC on improvement of heater performance and development of new heaters. About the time that we established test standards for the simulated test of switch heaters we began the consideration of other solutions to the switch failure problem. The burning of a fossil fuel for railway switch heating to melt and/or vaporize snow was a protection method we considered must be a temporary expedient. We are now more firmly convinced that the burning of fuel to melt and vaporize snow for switch protection must be replaced by more efficient methods.

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† Presented at Fourth Annual Sectional Meeting, Association of American Railroads, Communications and Signal Section.

Consideration of alternate solutions to the snow problem of railway track switches began at the same time as the work on thermal protection. The apparently obvious long-term solution is to replace the existing point switch by a new switch that does not fail from the presence of ice and snow.

THE HORIZONTAL AIR CURTAIN CONCEPT

In another field the Low Temperature Laboratory was investigating snow removal from surfaces by non-contact methods. One method under investigation was removal of deposited snow from a surface by the use of high speed air jets, which has shown considerable promise for all dry snow conditions. While conducting these tests it was observed that the air jet propelled snow a considerable horizontal distance before fallout of the particles.

This observation and the coincident knowledge of the railway switch failure problem raised the question of whether a switch might be protected by an air jet that would prevent snow from depositing in the critical areas. In early March 1972 some preliminary mathematical calculations were made on this idea and the analytical results indicated that the energy required appeared to be within reasonable and acceptable limits. The initial mathematical model of the concept was rather crude but served to show the order of magnitude on energy considerations. To investigate further, an experiment was set up immediately with an available blower to which a longitudinal duct with a slit nozzle was fitted. This assembly was placed adjacent to an experimental track section for test under natural snow conditions in the late winter and spring of 1972. This initial experimental test verified that the horizontal air curtain could maintain an area free from snow deposit and accumulation.

Additional experimental and analytical work continued during the spring and summer of 1972. The horizontal air curtain switch protector is premised on the idea of adding a horizontal velocity component to the existing vertical velocity component of falling snow particles such that the resulting velocity vector will cause the snow particles to be deposited on an area outside of the protected area. The terminal velocity (the vertical velocity component) of falling snow particles, whether snowflakes or ice crystals, has been established and measured by previous observers. The area of a switch that must be protected against snow deposit includes that between the open point and the adjoining stock rail, the slide plates within the switch, especially behind the closed point and the top of rail in order that snow does not fall into the critical zones.

While it was considered possible to have a single longitudinal duct and a transverse nozzle positioned along the outside of one stock rail to protect the entire switch, the analytical results showed that the energy requirement would be much higher than for other configurations. A single-sided configuration must provide sufficient velocity approximately five feet away from the nozzle to give the desired protection. An air jet issuing from a nozzle in free air suffers a velocity decay as a function of distance from the nozzle. Since the air curtain switch protector must function in either counterflow or crossflow wind conditions the single-sided configuration was discarded because of energy considerations. Another design that was considered was the double or selectable single-sided configuration. The active side would be chosen depending on wind direction. This means required the addition of a wind direction sensor and a duct damper selector. The double duct system outside of rail with the inward directed nozzles was rejected in that the snow could accumulate in large quantities along the centre line of the switch. The design that ultimately resulted was that of two outward directed longitudinal nozzles to clear snow from within the switch area to deposition zones outside the stock rails. In order to get the jet close to the point and stock rails a double duct system evolved with two longitudinal nozzles. The centre line of the switch was left open intentionally to allow maintenance.

MK I DESIGN AND TESTS

A symmetrical nozzle design was chosen primarily for simplicity of development when it was established from allowable clearance outlines that the longitudinal ducts could project above rail height. The longitudinal duct was shaped to give static regain in order that relatively uniform jet velocities were maintained along the long slit nozzle.

The mass flow of the horizontal air curtain switch protector is determined by three factors, (1) the required nozzle outlet velocity, (2) the length of the switch to be protected, (3) the snowfall rate. The depth of the nozzle and therefore the unit mass flow is dictated by (1) and (3). Knowing the mass flow and the required outlet velocity the losses of the duct system can be determined and a suitable fan and motor chosen. One of the less obvious design requirements of this system is that little or no snow should be induced in the air entry. By employing a low velocity re-entrant design this requirement is accomplished. The entry must have an upward velocity that is lower than the terminal velocity of most snow particles in order that only air is induced into the duct system. The design and fabrication of a full scale prototype horizontal air curtain switch protector was completed during the summer and early fall of 1972. This unit was equipped with a 7½-hp motor and fan. Cold chamber tests in the autumn under simulated conditions proved sufficiently encouraging that the experimental prototype was installed on an inactive isolated switch in November 1972, as shown in Figure 1. By early December the first few snowstorms had shown that this protection method was technically feasible. Before the winter of 1972-73 was over the switch was exposed to several more storms including an unusually high number of freezing rain storms. The horizontal air curtain managed to protect the switch not only in falling snow but also in the freezing rain. One of the snowstorms that was experienced during the first winter was of short duration but the conditions included an extremely severe snowfall rate at times exceeding 2 inches per hour with a crossflow velocity of 25 mph. The air curtain provided sufficient protection under these conditions.

Following the successful test on a non-operating switch during the winter of 1972-73, the CN agreed to install the MK I in their Montreal classification yard. An operating switch immediately below the secondary retarders at the main hump was equipped with the MK I in January 1974, as shown in Figure 2. In addition to observing the performance under the various snow and freezing rain conditions anticipated, it was necessary to evaluate the ruggedness of the different components of the device under operating conditions.

During the remainder of the 1973-74 winter and the following 1974-75 winter, there were two rather severe storms, one on December 16 and 17, 1974, with a snowfall of 10.1 inches mixed with freezing rain and a northeast wind at approximately 20 mph, and the other on April 3 and 4, 1975, with a snowfall of approximately 12 inches and a northeast wind 25-30 mph with gusts to 40 mph. The MK I unit maintained a clear, operable switch during both these storms. There were several other smaller storms during this time period which did not affect the operation of the switch.

New duct mountings were designed and installed during the winter of 1974 which were able to support the longitudinal ducts at the correct angle of 5° under the load of a man standing or walking.

The MK I unit was replaced early in the 1975-76 season by a newer design to evaluate a new duct mounting system.

MK II HORIZONTAL AIR CURTAIN

In the spring of 1974 the design of an improved model was undertaken primarily to modify the various components for possible manufacture. The MK II horizontal air curtain was installed on a switch in the Montreal hump yard adjacent to the MK I for direct comparison, see Figure 3.

During the winter of 1974-75 the MK II operated satisfactorily to protect the switch. There was no apparent or significant difference in performance between the MK I and the MK II version of the horizontal air curtain protectors.

As a result of the test trials with the MK I during 1973, 74 and 75 and the MK II during 1974-75, CN agreed to carry out an extensive field evaluation consisting of ten units distributed over the five regions during the winter of 1975-76.

MK III DESIGN AND FABRICATION

The field experience with the MK I and MK II showed that some additional changes were desirable for a production version. The crossduct, the elbows and the duct supports were modified.

A company was chosen as a supply source after consultations between the CNR, NRC and the licensing agency, Canadian Patents and Development Ltd. The manufacturer, Onex Industries Limited of Ottawa, undertook to fabricate the initial production run of the horizontal air curtains starting in late July 1975.

The first MK III unit to be delivered and installed was during November 1975 at the Ottawa Terminal.

MK III INSTALLATIONS AND OBSERVATIONS

Ottawa Passenger Terminal

In order to accommodate the installation of the horizontal air curtain on a switch at the east end of the yard, a crossduct elbow had to be provided to give sufficient clearance to a signal light.

The horizontal air curtain showed satisfactory performance in an early snowstorm during December 1975 as indicated by Figure 4. In January 1976 following a storm with 10 to 12 cms. of snow and winds at 25 mph, the switch was serviceable and clean. Although Ottawa experienced an above normal snowfall during 1975-76, no storm was of similar intensity to that experienced the previous winter in Montreal.

The ducts on the Ottawa installation experienced several severe hits that were ultimately traced to a low turntable on snow removal equipment.

Symington Classification Yard, Winnipeg, Man.

This unit was installed in a yard switch on December 5, 1975. There have been some snowfalls of note since installation. In particular, on March 2, 1976, there was a 7-inch snowfall with winds NW at approximately 30 mph. The switch remained clear and operable. Those responsible for track maintenance at Symington Yard have indicated complete satisfaction with the performance of the horizontal air curtain to date.

Mile 98.3 Drummondville Subdivision

This unit was installed east of the station at Drummondville, Que. on a main power line switch on December 18, 1975. Although the switch has remained snow-free for conditions encountered this winter, passenger trains crossing a diamond 30 feet east of the installation shake ice from the cars and drop it into the points of the switch. In these instances section forces are required to manually clean the ice from the switch.

Mile 273.1 Bala Subdivision

This unit was installed at Suez, Ont. on a main line power switch on December 22, 1975, but due to plate cutting of some of the ties the height was 1 inch above the design height of 1-5/8 inches above top of rail with the result that it was only partially effective, see Figure 6. This situation was remedied by National Research Council personnel on January 21, 1976. Since that time there has been considerable snow in the area and the switch has remained snow-free and operable. Also reports indicate that the unit has been effective under trail drag conditions.

Mile 112.2 Newmarket Subdivision

This unit was installed at Gravenhurst, Ont. on a main line power switch on January 22, 1976. There have been several snowfalls at this site since installation. In particular, on February 11

and 12, 1976, there was a 10-inch snowfall with winds NW 20 mph. The switch remained clear of snow and operable.

Joffre, Que.

This unit was installed on the engine lead in Joffre Yard on January 25 and 26, 1976. There has been considerable snow in the Quebec City area this winter. In particular, during a storm on February 17-19, 1976, there was a 15-inch snowfall with winds to 20 mph. The switch remained snow-free and operable. Also there was rain on February 26 and March 1, 1976. Under these conditions the switch remained clear with no evidence of ice forming on the points. All reports to date indicate that this unit has maintained a snow-free switch.

Mile 0 Redditt Subdivision

This unit was installed at Sioux Lookout, Ont. on a main line power switch on February 18, 1976. There has been some snow since installation and to date the unit has maintained a snow-free and operable switch. This location and the one at Suez may be considered as typical for Northern Ontario snow conditions.

Mile 57.9 Wainwright Subdivision

This unit was installed at Unity, Sask. on a main line power switch on February 9, 1976, but had to be lowered because of plate cutting. Because of the height above rail, the elbow was damaged and subsequently repaired as shown in Figure 5. The ducts were lowered on February 24, 1976. This has been a relatively snow-free winter on the prairies and there have been no snow reports since installation.

Mile 0 Clearwater Subdivision

This unit was installed and working at Blue River, B.C. on a main line power switch on February 26, 1976. Timber deflectors as shown in Figure 7 were installed. On February 27, 28, 29 and March 1, 1976, there was a major snowstorm with winds to 20 mph. The switch remained operable until March 1 when the switch rods became packed with snow. This resulted in overloading the power mechanism and sectionmen had to dig out the switch rods.

SUMMARY OF DESIRABLE IMPROVEMENTS

The tests this winter have been most revealing and valuable. Following is a list of improvements which will increase the dependability and universality of this device.

- The unit is presently powered by a 3-phase 550-volt, 7.5-hp motor. Other options must be investigated and developed.
- This winter's experience has shown that the elbows and the longitudinal ducts should not extend above top of tail.
- Timber deflectors are required adjacent to the ducts at both ends. In addition, timber deflectors could be installed at some distance from the unit to clear ice from the undercarriages of cars before arrival at the switch.
- The crossduct must be installed liquid tight.
- Angle of longitudinal duct jet must be maintained at 5° to the horizontal.
- There must not be any uneven plate cutting under point or stock rails.

— A universal type connection is required between the crossduct and the fan housing to accommodate areas where surrounding ground level is even with top of ties.

— A method of protecting switch rods from packing snow needs to be developed.

— The possibility of developing a unit to protect a 39-foot switch should be started.

— The possibility of developing a unit to serve more than one switch should be started.

CONCLUSIONS

1. The horizontal air curtain switch protector as presently designed is capable of maintaining a snow-free switch under the majority of climatic conditions encountered.

2. Snow packing around the switch rods can be readily corrected for the 1976-77 winter by a simple modification to provide an auxiliary air jet.

3. The other proposed improvements will allow for more widespread application of the horizontal air curtain switch protector.

4. This protection system offers the advantages of a lower capital cost, approximately half that of combustion heaters, a lower operating cost in terms of energy consumed, approximately 25% based on equivalent operating times, and a potentially much lower maintenance cost based on simplicity of design.

FIG. 1: MK I HORIZONTAL AIR CURTAIN ON AN ISOLATED SWITCH, WINTER 1972-73.

FIG. 2: MK I HORIZONTAL AIR CURTAIN INSTALLED IN MONTREAL CNR CLASSIFICATION YARD, WINTER 1973-74.

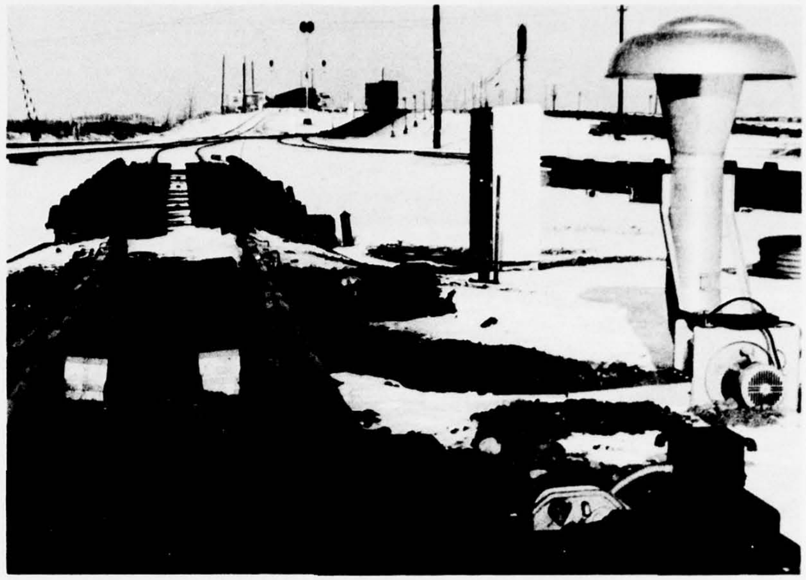

FIG. 3: MK II HORIZONTAL AIR CURTAIN INSTALLED IN MONTREAL CNR CLASSIFICATION YARD, WINTER 1974-75.

FIG. 4: MK III HORIZONTAL AIR CURTAIN INSTALLED IN OTTAWA, WINTER 1975-76.

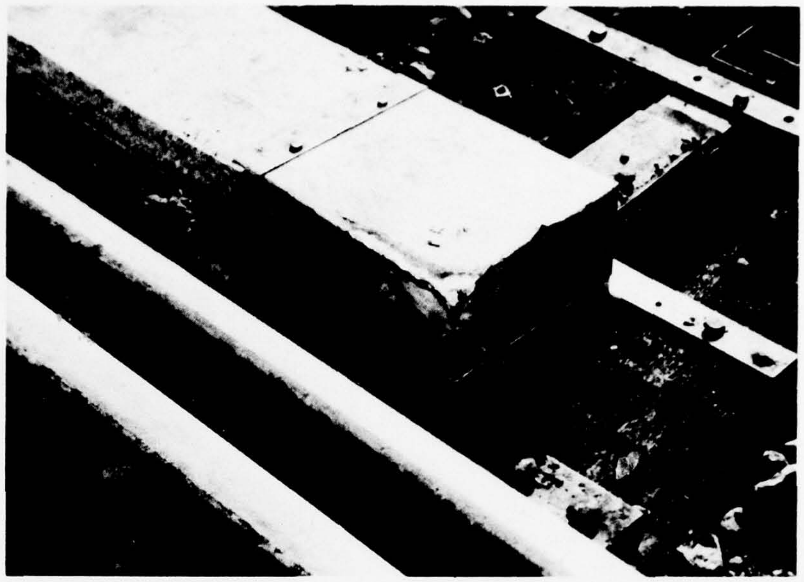

FIG. 5: UNITY, SASK. MK III ELBOW AFTER REPAIR, WINTER 1975-76.

FIG. 6: CAPREOL, ONT. MK III PRIOR TO LOWERING DUCTS.

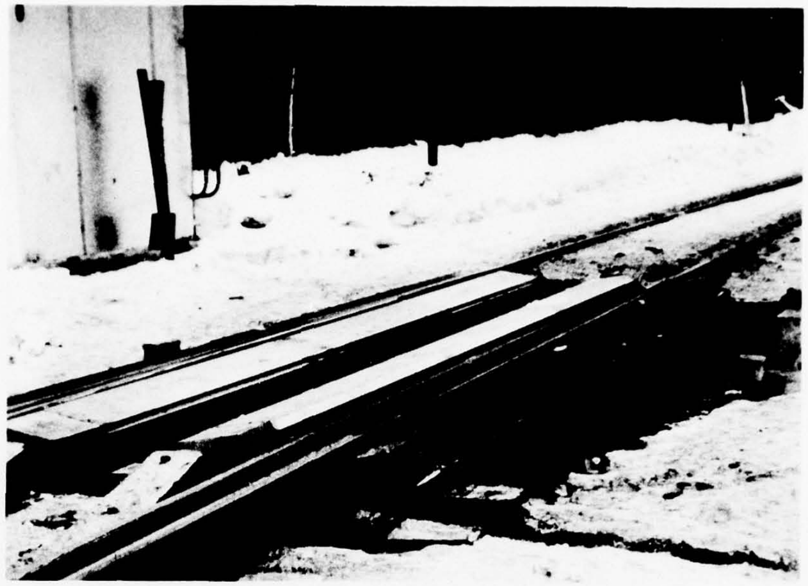

FIG. 7: BLUE RIVER, B.C. MK III WITH TIMBER DEFLECTORS.

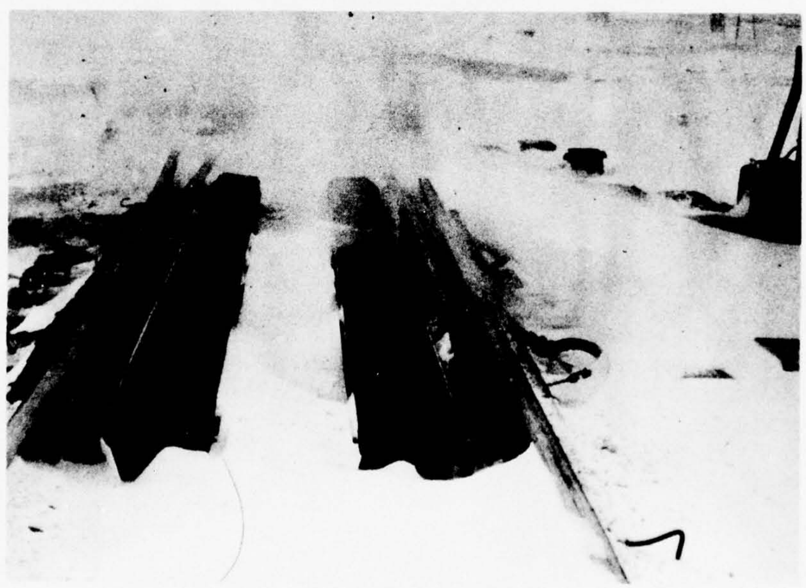

FIG. 8: MK II IN MONTREAL DURING STORM OF 3 AND 4 APRIL 1975.

A DISCRIMINATING POWER PULSE MAGNETO OPERATED BY MECHANICAL SHOCK

H.T. Stevinson and D.A. Baker

Flight Research Laboratory

National Aeronautical Establishment

1.0 INTRODUCTION

In order to improve spacecraft, aircraft, or vehicle safety, much thought is going toward devices that stand guard possibly for years in hostile environments and then must work extremely reliably in milliseconds to provide protection of some kind in the event of a crash or other sudden development. A very large assortment of devices is being used to try to accomplish this end result.

There are no known perfect ones since this could imply infinite reliability on demand, no inadvertent operations, zero mass, zero volume and zero cost among other good features such as discriminating between a non-serious degree of crash and a serious one.

Although vehicle crashes are being used here by way of example the possible scope of utility of these devices may be much broader.

A large class of crash detectors depends on the presence of a battery in the system. Loss of primary power may be the cause of a crash (lights going out) or the crash itself can disable the battery before the detector has acted. Where battery charging facilities do not exist in the system, primary batteries are used and bring with them the nightmare problems of trying to insure that they will deliver the essential power after 1 year, 10 years or even more before they are required to do so. The result of course is that even a perfectly reliable "g" switch would not always provide the required power pulse to initiate the action of the safety device.

Problems such as these lead directly to consideration of some form of magneto to provide the initial control power. If a suitable form of shock operated magneto could be devised it could offer at least two very fundamental advantages:

(a) Elimination of the dependance on batteries.
(b) Elimination of the threat that some form of fault condition will produce a power pulse when no shock exists.

Since Faraday publicized magnetic induction in 1831 and Lenz expounded the law $e = n\frac{d\phi}{dt}$

where e = induced
n = number of turns in coil of wire
ϕ = flux
t = time

a vast array of "magnetos" has appeared. Most of these are rotary devices driven by engines of some kind. A few are linear, producing alternating current in response to vibration or pulses in response to linear mechanical thrust. A few produce pulses in response to shock and most of these must be slow and large if they are to produce power pulses capable of acting without amplifiers or electrical power supply to initiate inflators or other types of safety devices directly. References 1, 2, 3 and 4.

Ref. 1 U.S. Patent 3130332 Zehfeld et al
Ref. 2 U.S. Patent 3736448 Hebel et al
Ref. 3 U.S. Patent 3774058 Abel
Ref. 4 U.S. Patent 3153735 Brannagan et al

In 1964 Brannagan et al obtained a patent for a device using a combination of many fundamental features to obtain an "inertia electromagnetic generator" that could discriminate against minor shocks but produce a pulse on experiencing more severe ones. This advanced type however had limitations in addition to its complexity and inevitable size, mass and high cost. Some of these were:

(a) It depended on a very small seismic mass operating a ball lock device subject to the vagaries of changing friction.

(b) It used energy stored in a belleville spring to help thrust the magnet and keeper apart. This energy then becomes a threat in the event that a fault condition might permit it to fling the magnet away from the keeper and produce an unwanted output pulse.

(c) The belleville spring is always under high stress and subject to some consequent creep which over the years could change the output characteristics.

(d) It is not repeatable without disassembly.

The device to be described in the following pages of this article uses a simple "hammer" principle to obtain and combine many simultaneous desirable features in a small simple mechanism.

1.1 Basic Principle

Briefly this basic principle is to use almost the whole magnet, coil and a thin overhanging main keeper as the "seismic mass" responding to shock. After a short movement under serious shock conditions the overhang collides with a shoulder of the surrounding case and large elastic forces in the metal abruptly stop the main keeper while the magnet and coil assembly continues on, to create a maingap and the required rapid flux change needed to produce a short but powerful electric pulse. Two small sectors of the main keeper remain fixed to the case. The magnet is attracted back to these sectors and when reset is held fixed to the case until the design shock limit is again exceeded.

Adoption of these principles allows other desirable features to be incorporated. These will be explained at convenient places in the following pages of this article.

2.0 THE DISCRIMINATING SHOCKMAGNETO

A small unit incorporating these principles is shown assembled in Figure 1a) and exploded in Figure 1b). The case cover with sector keepers attached occurs at the left of Figure 1b) followed by the main keeper, the case and the magnet and coil assembly. This same order is preserved in Figures 2a) and 2b). When the magnet assembly is placed in the case, the main keeper is clamped to the magnet by magnetic attraction but the whole seismic mass is free to move from left to right till the main keeper overhang strikes the shoulder seen inside the left end of the case. Friction is virtually eliminated by means of the coil spring roller bearings seen in the slots on the magnet assembly. Dual return springs serve a double purpose,

(a) they insure that the magnet, coil and main keeper unit will reset even if large magnetic air gaps occur, and

(b) they carry the output pulse current thus eliminating the need for flexible leads or brushes.

When the sector keepers and case cover are also added to the case, the magnet and main keeper move to the left urged by the weak return springs and the magnetic attraction between the main magnet and the sector keepers. The main keeper fits between the sector keepers and the device is reset when the magnet reaches the sector keepers and holds firm, resisting vibration and accelerations below the designed limit. The center pole of the magnet assembly is permanent material like Alnico 5. The outer pole is soft iron and the coil between them is often a dual winding potted in Epoxy resin.

A cross section drawing of an assembled unit is shown in Figure 3. The numbered flags lead to the following components:

(1) Output terminal insulator
(2) Return spring insulator and guide
(3) Adjustable case endcap
(4) Return springs
(5) Overrun bumper ring
(6) Return spring insulation on magnet
(7) Coil spring roller bearing
(8) Threaded case
(9) Adjustable case endcap
(10) Soft iron outer pole of magnet
(11) Main keeper with overhang.

This type of adjustable unit was first made for research purposes. The characteristic length used to determine the scale of different sizes of units is the diameter of the Alnico center pole in inches. Figure 4 shows a few of the models made during the evolution of the present design from an experiment in which a magnet held up a keeper attached to a long rod. A sliding mass could be dropped down the rod till it hit a stop at the rod end, whereupon a tensile shock wave travelled up the rod to violently pull off the keeper and generate a powerful pulse. (Over 500 watts peak power can easily be generated this way.) The models in Figure 4 from left to right have scales 1.0, 1.233, 1.233 without spring bearings, 1.233 with spring bearings, 1.233 with bearings but a 15% winding window instead of 30%, 0.913 adjustable model, 0.913 fixed model, 1.68 adjustable model.

3.0 THE FORCE FUNCTION

Figure 5 shows a force function graph of a 1.233 scale adjustable model with spring bearings, calibrated for repeated operation to yield the same pulse energy each time it experienced a given shock function. Calibration for repeated use and for other purposes will be explained in the section on calibration.

In Figure 5 the line (a), (d) and (e) at $1^\circ 55'$ represents the return spring force function of force F vs. magnet assembly stroke length ℓ_s. The return springs are normally biased so that the unit will reset at any attitude expected in service. The null force point for these springs is at Point (a) in this example. When reset the magnet assembly is considered to be at the origin point (0,0). If a force F is applied to the magnet assembly to force it slowly through a complete stroke by actually pushing on the center pole the shaded force function would result. The sloping line (b) and (c) at $61^\circ 15'$ represents the elasticity of the end cap and structure holding the sector keepers. At point (c) the prestroke gap begins to form and the magnetic attraction diminishes on a parabolic curve until it fades into the return spring function around (d). From (d) to (e) with this calibration only the return springs resist the motion (neglecting almost negligible bearing friction). At point (e) the force function begins to rise on the line (k) and (f) which represents the elastic stiffness of the main keeper and case end that has now been encountered by the overhang on the main keeper. At the point (f) the magnet begins to tilt slightly, restricted by the spring roller bearings. A wedge shaped gap is now forming between main keeper and magnet poles. As the magnet proceeds a low point (g) is passed and the peak at (h) is reached whereupon the magnet loses contact with the keeper. Between (h) and (i) the gap is increasing and the magnetic attraction diminishes on another parabolic curve related to the magnet design. At point (i) the bumper ring is encountered and the force begins to rise along the line (i) to (j) representing the elastic stiffness of the low temperature plastic bumper. (A metal belleville spring bumper could of course also be used if desired.) The point (j) is arbitrarily chosen as the end of the bumper stroke but of course a more severe force could push the magnet beyond (j). This will be discussed more fully in the section on calibration to follow. In the section on theory to follow the equations for the different parts of the force function curve will be presented.

For now a qualitative description of the action of the device in the presence of shock will be given. It is important to recall that the moving mass inside the case includes the main keeper in the region 0 to (e) but does not include the main keeper in the region beyond (e) in Figure 5.

When a shock begins to decelerate the case no relative motion between the magnet and case occurs until the shock reaches a level that drives the magnet-keeper mass (m_2) over the force peak at (c). For the moment it is convenient to think of the mass (m_2) being of unit magnitude so that the force-displacement curve in Figure 5 could also be a deceleration-displacement curve. The mass m_2 then can only decelerate at a rate given by this curve and depending on the displacement position reached in the case between points (o) and (e). Beyond point (e) the magnet mass (m_3) will be less than unity because the keeper has been left behind at the stop. The deceleration line for m_3 will thus be somewhat higher than the force function shown from (e) to (j) and beyond.

In crash conditions the case deceleration would be expected to be considerably greater than the magnet-keeper deceleration function for some time. The magnet will be travelling faster than the case and proceeding towards point (e) on Figure 5. As the magnet moves past (e) to f, g and h the deceleration on it greatly increases and may become greater than the case deceleration at the moment. The magnet velocity may still be considerably higher than that of the case so the magnet (alone now) may proceed well along toward (i) or may even impact the bumper and proceed toward (j) before its velocity is brought down to that of the case and then below it, so that a tendency to return toward point (o) and reset, may occur as the shock to the case diminishes or ceases with time.

The magnitude of the force function will be reduced in places as the magnet returns to reset, because of the demagnetizing effect of the air gaps created during the forward stroke. When the gaps close on reset the force function will return to that of Figure 5 because this figure represents a device that has been calibrated for repeating operation. As will be shown in the section on calibration the unit can be calibrated for single pulse operation or can be calibrated in a hybrid fashion so that the prestroke from 0 to (e) is repeatable but the mainstroke from (e) to (j) is for single pulse operation.

Actual values of m_2 and m_3 obtained in the research model at 1.233 scale were

$$m_2 = 1.36 \text{ lb}_m$$

$$m_3 = 1.10 \text{ lb}_m$$

4.0 PERFORMANCE

Figure 6 shows an example of the performance of the smallest unit made so far, namely a scale 0.913 unit. This unit has been calibrated for repeating operation and subjected to a halversine shock function of time that reaches a peak of about 45 g's and has a duration of about 30 milliseconds. This function is labelled "deceleration" in Figure 6. The resulting change in velocity due to this shock is obtained by integration of the shock function and is shown labelled "drop in velocity" in Figure 6. The trace labelled "pulse voltage" is the output voltage from the magneto appearing across its 0.93 ohm resistance load. The trace labelled "pulse energy" is the product of the load voltage and current, integrated to give the energy output as a function of time. Each step in this curve yields the energy from the corresponding voltage pulse below it.

Figure 7 shows a similar set of traces from the same magneto unit but in this case the unit has previously been calibrated for hybrid operation. The shock function is almost the same but the voltage and energy output are much larger. The voltage has increased from a peak value of about 2 volts and a peak power of 4.3 watts for the repeating mode to about 5 volts and 25.9 watts for the hybrid mode.

The energy traces show an increase from 6 watt milliseconds to 54 w.ms. This extra energy has been obtained, as can be seen, by firing later after more shock energy has developed as indicated by the drop in velocity of 5.6 mph before the pulse begins in the first case and 10.2 mph in the second case.

The vibration starting on the deceleration curve when the voltage pulse begins is thought to be caused by the main keeper vibrating after striking the stop on the case coupled with the fact that the test car carrying the unit is so light that it is affected by this event whereas on a full scale car the mass would swamp out the effect, given a good solid mount for the unit.

Figure 8 shows the same magneto unit working into a 2.51 ohm load consisting of fine wires imbedded in an igniter device. The wire is melted or broken as a result. The deceleration function is almost the same, the voltage pulse seems low at about 0.6 volt but this could be the voltage at which the device shorted due to blast action. The step in the energy trace corresponds to an energy of about 6.2 watt milliseconds at which the circuit shorted and no more energy could go into the load. The two extra traces below show the current pulse through the load up to the time of shorting and the microphone response to the sound of the igniter device operating as it should.

5.0 LARGER SCALE UNITS

Figure 9 shows the result of a series of shock tests of a 1.233 scale shockmagneto mounted on a small scale car run down a ramp into an inflated tennis ball. (Providing a close approximation to a halversine shock function*.) It is seen that this unit begins to respond to a shock function characterized by a velocity drop (ΔV) between 2 and 3 miles per hour, as calibrated. The energy in the first pulse (E_{N_1}) rises very steeply at first and then becomes linear continuing to increase with (ΔV). This is as it should be because the faster the magnet creates the gap the higher the voltage but at the same time the duration of the pulse is shorter. Only because the power output is proportional to the voltage squared does the energy continue to increase. It is seen that considerable extra energy may come from the negative pulse but this can be considerably later than the positive pulse so in some cases it may be necessary to suppress the negative pulse by shunting it through a diode or other means.

Figure 10 shows the result of experiments to prove that the shockmagneto has been optimized for low resistance loads in the neighborhood of one ohm. This is a still larger scale unit at 1.68 scale operating on a modest shock yielding a total velocity drop of 8.23 to 8.56 mph during the series.

The positive pulse energy reaches a suitably broad optimum around one ohm. The ideal load resistance can be changed by changing the number of turns in the winding of the magneto coil. Recent models used twin coils that can be connected in series or parallel to cope with two different ranges of load. The difference between the (O, C, V) open circuit voltage line and the (V_{pk}) voltage peak line yields the internal voltage drop from which a form of internal impedance can be calculated but is not shown in Figure 10.

6.0 OPTIMIZING STROKE LIMIT SETTINGS

Figure 11 is obtained by scaling the results from several sizes of shockmagneto. The stroke length is scaled by dividing it by the 1.385 power of the scale. The output energy is scaled by dividing by the 3.877 power of the scale. This brings the curves of a range of sizes of units into a group where conclusions are conveniently drawn. Before scaling, the results were all corrected to represent the case where the applied halversine shock produces a rapid drop of 12 miles per hour in magneto velocity.

---

* $$a = \frac{K}{2}\left(1 - \cos\frac{2\pi t}{p}\right)$$

where
- a = acceleration (g's)
- k = peak value of acceleration (g's)
- t = time (seconds)
- p = period of halversine (seconds)

Scale of Magneto	Stroke Scaling Factor	Energy Scaling Factor
σ	$\sigma^{-1.385}$	$\sigma^{-3.877}$
0.913	$\frac{1}{.8816}$	$\frac{1}{.7027}$
1.00	$\frac{1}{1.0000}$	$\frac{1}{1.0000}$
1.233	$\frac{1}{1.3365}$	$\frac{1}{2.2525}$
1.68	$\frac{1}{2.0514}$	$\frac{1}{7.4735}$

It may be concluded that the output energy under these conditions increases approximately as the 3.9 power of the scale and that the optimum main plus bumper gap lengths increase approximately as the 1.38 power of the scale and should be approximately 0.07 inches at scale 1.0.

The increase in available energy by the 3.9 power of the scale is a powerful function so a small increase in size yields a large increase in available energy. About 7.5 times between scale 1 and scale 1.68. The mass however increases as the 3.0 power of the scale so the

$$\text{ratio} \quad \frac{\text{Energy}}{\text{Unit Mass}} = \frac{\sigma^{3.9}}{\sigma^{3.0}} = \sigma^{0.90}$$

The energy per unit mass then increases almost proportionally with the scale or in other words one big unit should be better than several small ones. This is no doubt because the bigger units can use a longer stroke as a result of the greater distance between inner and outer poles and the consequent greater distance that the fringing effects of the field can be significant. The larger one would be somewhat slower because it has to go farther, than another optimized unit at a smaller scale. This can be misleading in certain cases because the energy required must be suitably scaled to each size of unit for a consistant design. If the same energy is required from a large and a small unit the large one will be lightly loaded and may reach the required output sooner than the small one.

7.0 EFFECT OF PRESTROKE LENGTH ON ENERGY CONTOURS AT CONSTANT SCALE AND CONSTANT LOAD RESISTANCE

Figure 12 shows the results of many tests of a scale 1.233 magneto on a load resistance of 0.86 ohms. (Optimum load.) These contours are drawn for a case where an energy of 6.67 watt milliseconds is of interest because it operates a certain load device. The contours show the relation between available prestroke length and drop in velocity due to applied shock, for the energy in the first pulse of the magneto to reach levels of 6.67, 13.34, 20.1, 26.7 watt milliseconds. It can be seen that if a small energy is required from a given shock magneto unit, the length of prestroke is significant but if the demand is for almost all it can deliver at the top speed of the test series then the prestroke length available makes little difference to a unit calibrated for repeating type of operation.

8.0 CALIBRATION

It has been mentioned that the discriminating shock magneto may be calibrated for use in three different modes of operation. These are:

1) Repeating Mode 2) Single Pulse Mode 3) Hybrid Mode

If the device is required to produce the same energy again and again from repeated shocks of the same magnitude then it would be calibrated in the repeating mode.

If only one pulse is required during the service life it could be calibrated in the single pulse mode.

If many small shocks are expected before the big one that counts arrives the unit might be calibrated in the hybrid mode.

Briefly, calibration consists of magnetizing the shockmagneto in the assembled reset condition well into saturation of the permanent magnet center pole, followed by forcing the magnet assembly through all or part of the strokes that may occur in service. Saturating the magnet serves to standardize the starting point for calibration. This is done by connecting a large current source to the magnet coil through a metering circuit limiting the current pulse to about 25 milliseconds. This high current could damage the unit if left on much longer but the time available allows the current to build up enough to saturate the magnetic material while the thermal capacity of the wires and surroundings limits the rate of temperature rise of the wires so that the pulse is over before harm occurs.

8.1 Repeating

Once the magnet has been saturated the unit can be calibrated by demagnetizing to the desired degree. For repeating operation the magnet is forced by a tool or machine several times through the prestroke, the mainstroke and the bumper stroke as far as it will ever likely go in service. The air gaps so formed allow poles to form that have a demagnetizing effect on the magnet. The magnet strength is thus reduced to a level that it can support at any gap length it will encounter. As the magnet is allowed to reset, the reduced magnetic flux will build up partially because it does not have to fight a long airgap. The magnet is no longer operating on the main hysteresis loop of the material but on a minor loop which it can follow back and forth repeatedly every time a magnet stroke occurs so that repeating operation is achieved and no further magnetizing of the pulse generator should be required unless the unit is disassembled or its adjustment altered.

8.2 One Pulse

If only one stroke will be needed in service the unit is calibrated by saturating and not forcing the magnet to move al all. It remains at full strength, requires a considerably larger shock to produce a pulse but is capable of providing many times the energy that a unit the same size could provide in the repeating mode. The force function would have much larger peaks at both (c) and (h) in Figure 5.

8.3 Hybrid

A mixture of both calibration methods can be used because the unit has a prestroke and a mainstroke. In this case the device would first be saturated and then forced through the prestroke only (to point (e) in Fig. 5). This would bring the first force function peak down from the high "one pulse" level to a magnitude greater than peak (c) but considerably smaller than in the "one pulse" case. The prestroke would then be acting in a repeatable fashion while the mainstroke would still be of the "one pulse" type.

In both "one pulse" and "hybrid" modes the unit would have to be remagnetized if it were to be used again after a serious shock. With modern vehicle design a serious shock could involve considerable damage to the vehicle so remagnetizing could be part of the repair procedure. For a type of service where this is not feasible a repeating unit could be used, of a somewhat larger size to provide the required energy.

9.0 THEORY

Equations can be written for all the parts of the shockmagneto force function of Figure 5. One way to express the curve of magnetic force (F_g) versus stroke length (ℓ_s) is to recognize that these curves have a parabolic form* which can be specified by a suitable power series. Given the force function of Figure 5 and some tracing paper it is soon found that a good fit for the region between (h) and (i) is obtained using the simple formula

$$\bar{y}^2 = 4\,p\bar{x} \tag{1}$$

for a parabola at the origin, if p = 3 and the curve is translated from the origin to point (25.3, 4.75) and rotated 45°.

It will be noted that

$$F = 5y \tag{2}$$

and

$$\ell_s = 0.01x \tag{3}$$

in Figure 5. This change of variable is introduced to yield equal scales on both axes for ease in translation and rotation of the parabola by analytic methods a bit later. The force function of Figure 5 is obtained initially by placing a shockmagneto unit in a machine to plot the force function while a probe pushes the magnet through the complete stroke available.

It turns out that the force function of Figure 5 is made up of straight lines and two parabolic segments. The equations for each section are written as follows:

In the range ($0 < x < x_c$)

$$y = 1.823\,(0.4 + x) \tag{4}$$

describes the very short line from $x = 0$ to $x = x_c$ at point (c).

For $x_c < x < x_d$

$$x^2 - 7.963xy + 15.84y^2 - 6.121x - 55.183y + 52.29 = 0 \tag{5}$$

describes the parabolic curve representing magnetic attraction for the fixed "sector keepers" and the added force of the return springs.

For $x_d < x < x_e$

$$y = 0.0333\,(10.9 + x) \tag{6}$$

represents the straight line return spring force only, in the range from (d) to (e) in Figure 5.

For $x_e < x < x_f$

$$y = 38.18\,(-22.7 + x) \tag{7}$$

represents the straight line (ef) due to main keeper and case elasticity as they make contact.

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* Permanent Magnet Handbook – edited by Earl M. Underhill – Crucible Steel Co. of America, The Oliver Bldg., Mellon Square, Pittsburgh 22, Pa.

For $x_f < x < x_h$

$$y = y_h \tag{8}$$

will be a good enough approximation for our present purpose because this section is so very short.

For $x_h < x < x_i$

$$x^2 - 2xy + y^2 - 58.07x + 24.13y + 932.5 = 0 \tag{9}$$

is the equation representing the parabola $\bar{y}^2 = 4\ p\bar{x}$ Equation (1) which has been shifted from the origin to the point (25.3, 4.75) and also rotated +45 degrees to coincide with the force function between points (h) and (i) in Figure 5. A good fit is obtained by letting p = 3 in Equation (1). Equation (9) represents the sum of the magnetic and return spring forces. If the return spring force is subtracted to give magnetic force only, a slightly different equation results, namely:

$$x^2 - 2.1261xy + 1.13y^2 - 62.74x + 29.9y + 1030 = 0 \tag{10}$$

which results from equation $\bar{y}^2 = 4\ p\bar{x}$ translated to point (25.3, 3.63) and rotated +43.25° with p = 3.2.

Equation (10) is useful for finding the flux (ϕ) in the magnetic gap as a function of stroke (or air gap length) from which the rate of change of flux with stroke $\frac{d\phi}{d\ell_s}$ may be obtained.

Equation (9) is useful in obtaining the rate of change of magnet position with time $\frac{d\ell_s}{dt}$ using the laws of motion.

The two rates combined produce the rate of change of flux with time

$$\frac{d\phi}{dt} = \frac{d\phi}{d\ell_s} \cdot \frac{d\ell_s}{dt} \tag{11}$$

which will be used later to find the induced electro motive force in the magnet coil according to Lenz law, namely:

$$e = n \frac{d\phi}{dt} \tag{12}$$

where

e	=	e.m.f. in coil
n	=	number of turns in coil
t	=	time

Meanwhile it remains to write the equation for the section of Figure 5 from (i) to (j), namely:

For $x_i < x < x_j$

$$y = 10.08\,(-31.6 + x) \tag{13}$$

which also holds good for some distance beyond the point (j) in many cases.

Armed with this set of equations it is now possible to begin to explore the performance features of this type of "discriminating shockmagneto" or "shock operated electric pulse generator".

The flux ϕ may be derived from the magnetic force Equation (10) by means of the formula:

$$F_g = \frac{\overset{-6}{0.577}\ lb_w}{in^2\, gauss^2} A_g B_g^{\ 2} \qquad (14)^*$$

and

$$\phi = A_g B_g \qquad (15)$$

where F_g = magnetic force across air gap
A_g = area of air gap
B_g = flux density in air gap.

Equations (14) and (15) combine to form the required relation between flux and magnetic force namely:

$$\phi_g = \sqrt{\frac{1\ in^2\, gauss^2}{\overset{-6}{0.577}\ lb_w}}\ A_g^{\ 1/2}\ F_g^{\ 1/2} \qquad (16)$$

Equation (10) may be differentiated with respect to x and the result combined with Equations (2), (3) and (16) to obtain the rate of change of flux with magnet position or stroke

$$\frac{d\phi}{d\ell_s} = 175{,}745\ \frac{-x + 1.063y + 31.137}{-1.063x + 1.130y + 13.455}\ y^{-1/2} \qquad (17)$$

Since it is $\frac{d\phi}{dt}$ *we want* Equation (17) is only the first step and as indicated by Equation (11) it is now $\frac{d\ell_s}{dt}$ the rate of change of magnet position with time that must be determined if we want to end up being able to calculate the output performance of the magneto.

This step involves the laws of motion and is realy a 3 mass problem involving mass m_1 the total mass of the vehicle carrying the shockmagneto, mass m_2 which consists of the magnet and main keeper assembly during the prestroke and the magnet m_3 alone in the main and bumper stroke regions. Presently an attempt is being made to reduce this to a 1 mass problem by

(a) Using a stylized shock function to represent the shock applied to the vehicle.

(b) Treating the problem in 2 parts so that m_2 in the first part becomes m_3 in the second part by a change in magnitude.

This assumes that the main keeper stops between e and f in Figure 5 and that we are not interested in the vibration of the keeper. This work is ongoing at the present time in the hope that it will offer a convenient means of understanding and predicting performance and applications and will supplement the ramp car results in useful ways. For more demanding situations, of course, the 3 mass concept can be retained and the complex force function specified by Equations (4) to (9) and (13) may be used as a typical example of a scale 1.233 unit force function.

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* $\overset{-6}{0.577} = 0.577 \times 10^{-6}$

10.0 INADVERTENT OPERATION

10.1 Overvoltage Pulses on Vehicle Electric System

Almost all vehicles and aircraft have pulses in their electrical systems induced by such things as switching off inductive loads. Two thousand volt pulses on a 24 volt aircraft system have been recorded. Often their source is not known. These are very short duration but may contain plenty of energy to operate a hot wire device. These very short pulses may have very steep wavefronts making them difficult to isolate from any circuit that is connected to them because it depends on power from them. Since the discriminating shockmagneto does not need electric power it does not have to be connected to the vehicle electric system. The hot wire device connected to the magneto can thus be much more easily isolated from spurious and often mysterious pulses that could otherwise cause a highly unwanted inadvertent operation of a safety device.

10.2 Inadvertent Operation by Electrostatic Discharges

It is normal practice for designers creating hot wire activated systems to assume that the human body has a capacitance of 500 picofarads and that the electrostatic voltage induced on a person can be considered to be 18,000 volts. These figures must be for a person on a flat floor. When a person is enclosed in a 6 sided metal vehicle the capacitance can be much greater. Measurements made with bare feet and only a thin plastic carpet have shown over 7000 picofarads is possible.

It has also been shown that rubbing or sliding on plastic can induce over 50,000 volts. (For instance, sliding across a plastic car seat on a hot dry summer day.)

The energy stored in a capacitance is given by

$$E = \tfrac{1}{2} CV^2$$

where

E	=	energy (joules or watt seconds)
C	=	capacitance in Farads
V	=	voltage

500 pf and 18,000 volts would yield an energy of 81 millijoules (or watt milliseconds) 7000 pf and 50,000 volts would yield an energy of 8750 millijoules (or 8,750 watt milliseconds). The possibility thus exists for electrostatic discharges over a hundred times stronger than some might expect and 1000 times greater than required to operate some hot wire safety devices. This calls for not only a high degree of safety circuit isolation but also calls for the use of much less sensitive hot wire devices. Use of insensitive devices creates a problem for any system depending on the vehicle battery because battery failure may have caused the emergency in the first place. This fact demands an auxiliary power storage device such as a capacitor to provide energy till the safety system has operated. On a 12 volt system this implies the addition of very large but low leakage capacitors, so dangerously sensitive hot wire devices have been used on such systems. Energy available from the shockmagneto increases proportional to the 3.9 power of its size. A small increase in size can therefore provide energy to drive much less sensitive hot wire devices.

11.0 CONCLUSIONS

A discriminating shockmagneto has been devised with this objective in mind: to extract electrical energy from a mechanical shock with a unit that can discriminate between serious and non serious shocks and produce large currents and energies from serious shocks. These large current pulses are expected to be ideal for operating low impedance hot wire devices. A simple "hammer" principle applied to magneto design has made it unnecessary to use a complex of many principles in a device in order to get large energy pulses from a coil and magnet with very short time delay after

a shock pulse has demonstrated that it has become serious. In order to keep size, mass and cost to an absolute minimum for airborne and other applications almost the entire magnet and keeper assembly has been used as a seismic mass. Just as an anvil stops a hammer so does a shoulder on the magneto case stop the main keeper, while the main mass including a permanent magnet center pole, a soft iron core and a dual coil winding proceeds to produce a sudden gap which in turn induces a fast high current, high energy pulse. Such a unit has evolved from a concept to a small unit that can be hermetically sealed and has been optimized to work best with resistance loads in the range from 0.5 to 1.5 ohms or 1.5 to 3.0 ohms using 2 coils in parallel or series as required. The "seismic magnet" moves on coil spring roller bearings with near zero friction but accepts shocks from the front over a wide angle with considerably better than cosine law response.

Curves are presented that allow the unit to be scaled to larger or smaller sizes and still have optimum available air gaps for high energy output. Curves are also presented to show the effect of varying the prestroke length and the effect of various shock intensities on output. By taking advantage of the "memory" inherent in the permanent magnet the device can be used in many ways to gain advantage. Three of these — the repeating mode, the single operation mode and the hybrid mode — are of special interest.

Under certain conditions it may be useful to have a device that can be insensitive to a first shock and then automatically change sensitivity to following shocks. It might even be useful to have a device whose sensitivity to shock could be remotely controlled. Use as a pulse power source for distress signalling devices is another possibility.

LIST OF SYMBOLS

Symbol		Definition
F_g		force function due to magnetic attraction across a gap (pounds)
ℓ_s		length of stroke of magnet producing gaps in the magnetic circuit
y	=	$\frac{F}{5}$ = force in (5 pound units)
x	=	$100\ell_s$ = magnet stroke in (hundredths of an inch)
F		static force acting on moving mass (pounds)
ϕ		flux in magnetic circuit (gauss)
t		time (seconds)
e		electro motive force generated in coil of wire on magnet (volts)
n		number of turns in coil
A_g		area of gap $(\text{inches})^2$
B_g		flux density in gap (oerstedts)
lb_w		pound weight = $lb_m \times 32.2$ feet/sec^2
lb_m		pound mass
in		inch

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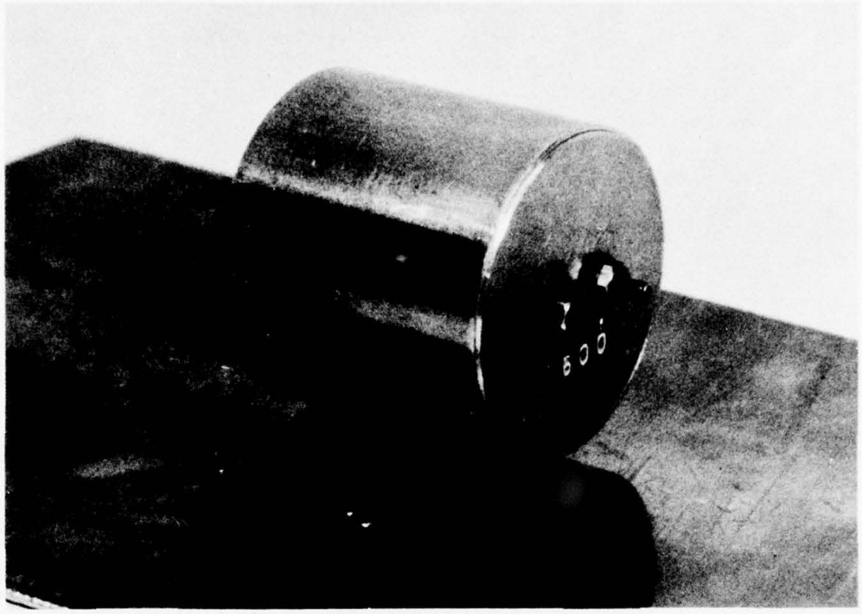
Mr. Fred McCaffrey of the N.R.C. Structures Laboratory freely gave periodic advice and guidance on the overall automotive situation and the latest Stapp Conference findings; Mr. D.F. Daw and his staff provided valuable advice and instruments on occasions; Mr. Brian Usher and his staff spent a large amount of time on machine work for the long series of shockmagneto models used in experiments; Jim Edwards gave freely of his experience with plastics; Bill May and Len Nesbitt did the photographic work.



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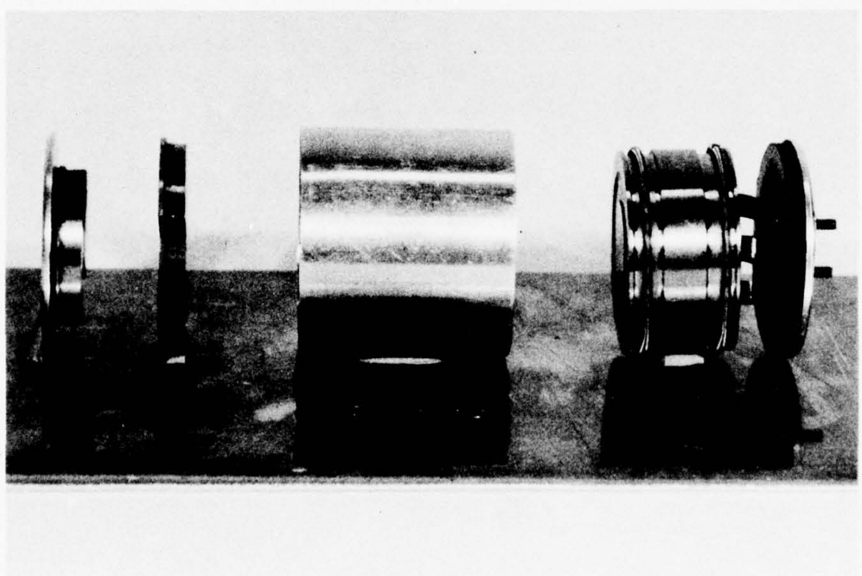
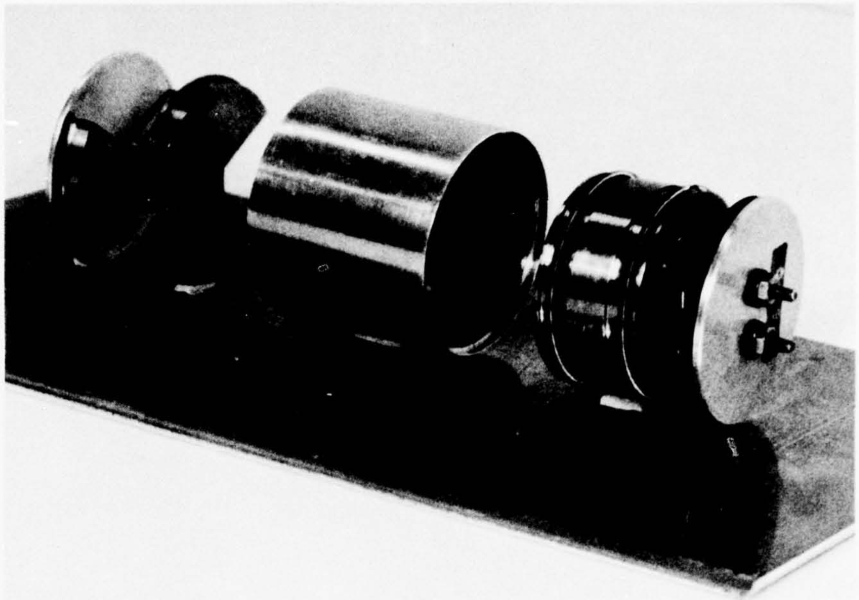


b)

FIG. 1 DISCRIMINATING POWER PULSE MAGNETO OPERATED BY MECHANICAL SHOCK

SCALE 0.913



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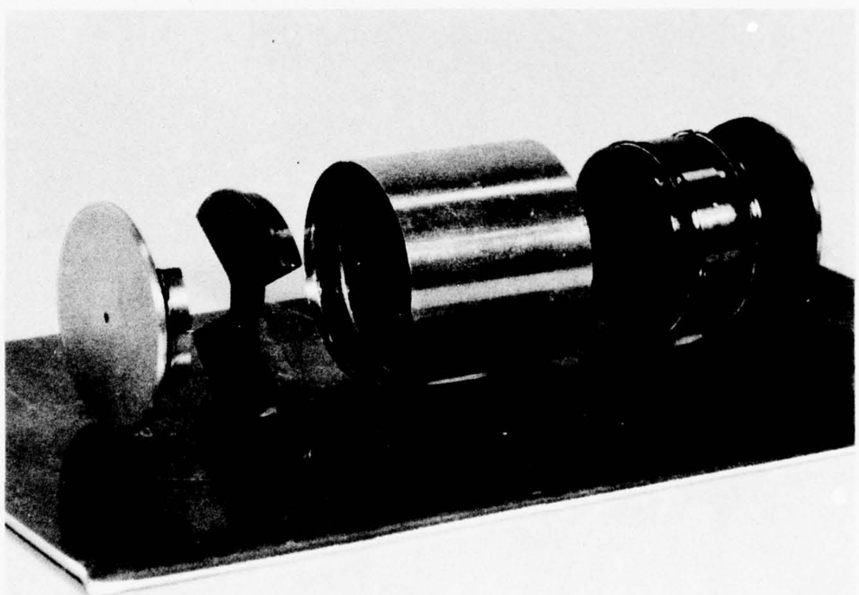


b)

FIG. 2 DISCRIMINATING POWER PULSE MAGNETO OPERATED BY MECHANICAL SHOCK

SCALE 0.913

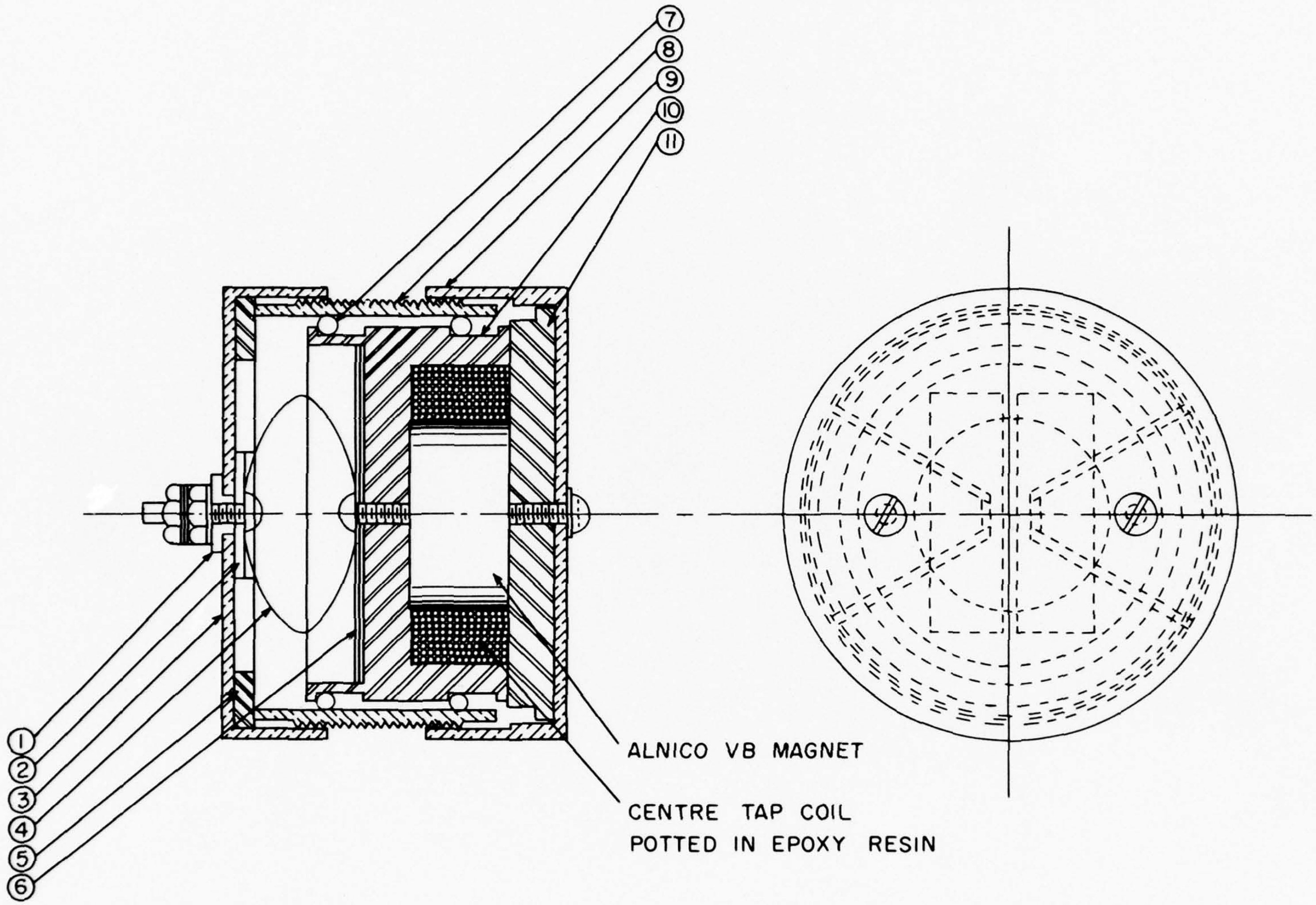


FIG. 3 RESEARCH TYPE ADJUSTABLE DISCRIMINATING POWER PULSE MAGNETO

SCALE 1.233

FIG. 4 SELECTED SAMPLE OF MODELS MADE DURING EVOLUTION OF DISCRIMINATING SHOCK MAGNETO

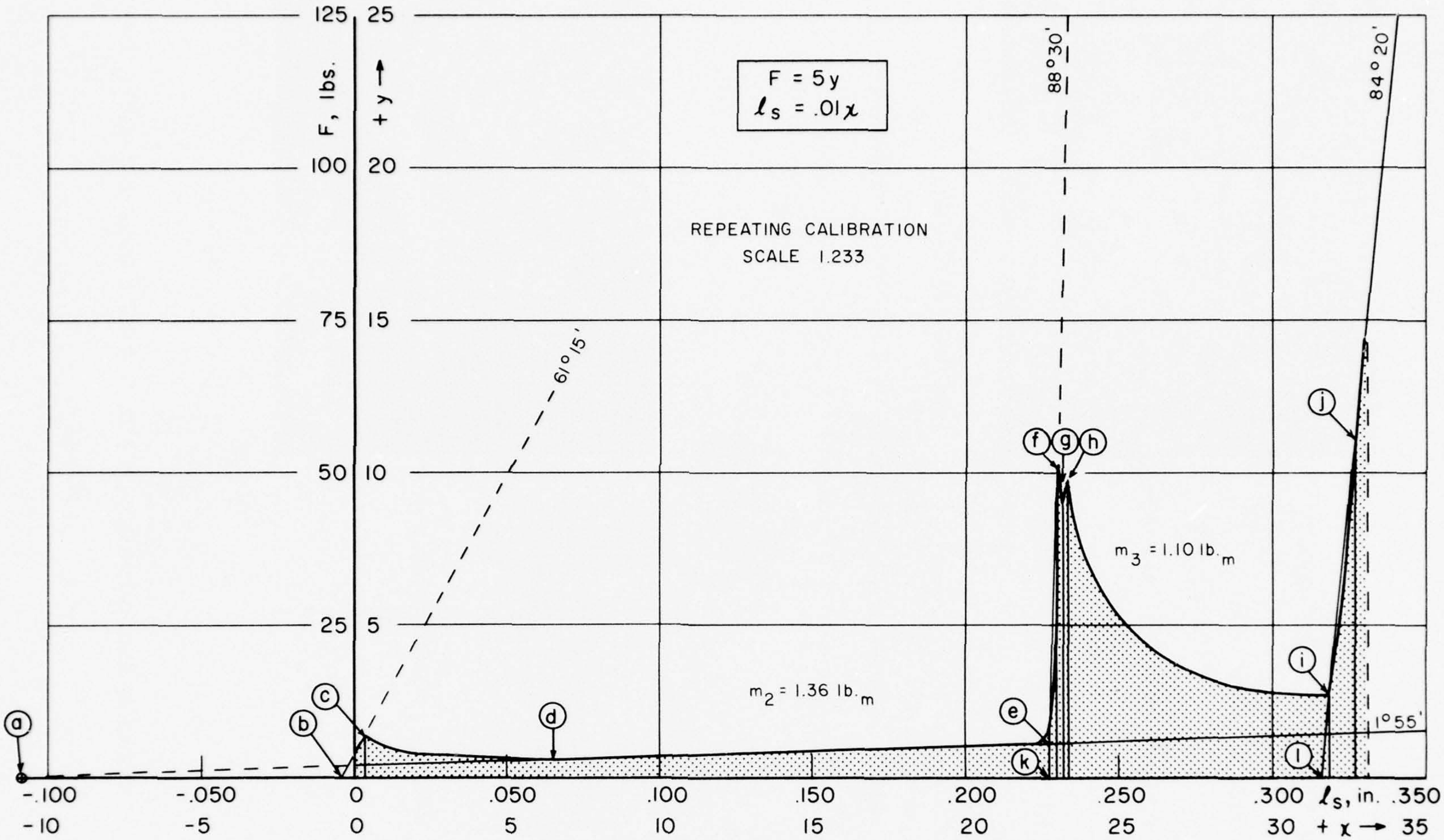


FIG. 5 FORCE FUNCTION OF SHOCK ACTUATED ELECTRIC POWER PULSE GENERATOR

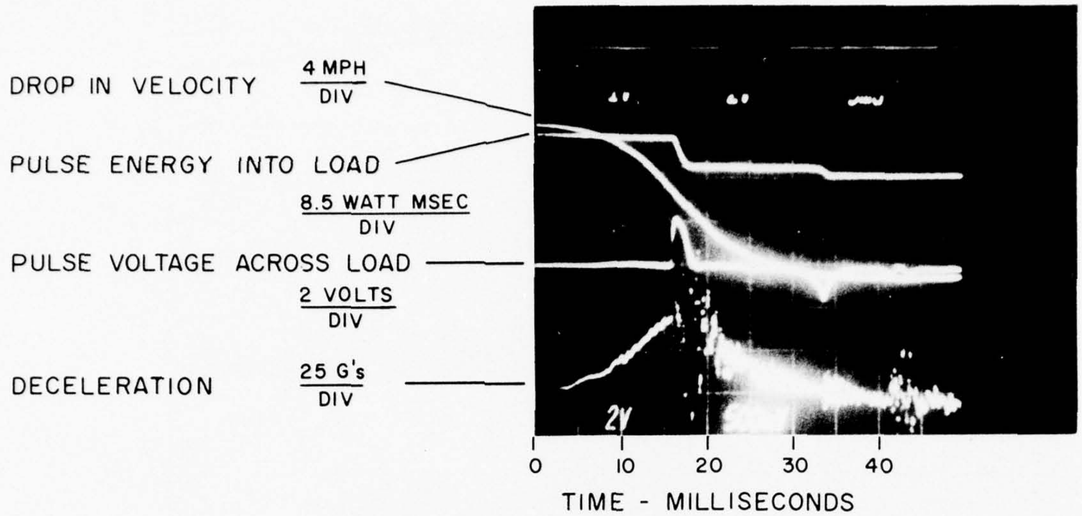


FIG. 6 MAGNETO PERFORMANCE — REPEATING CALIBRATION

SCALE 0.913

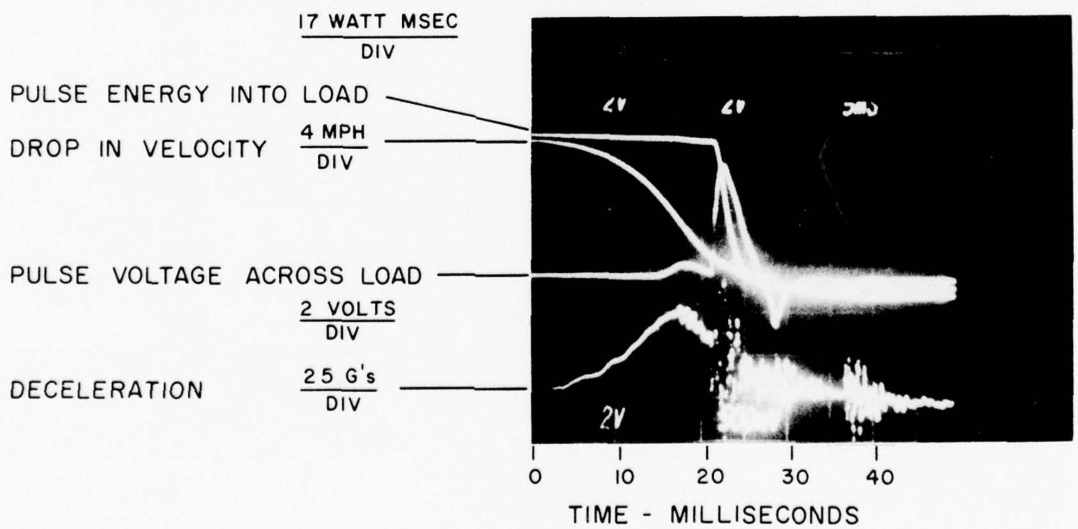


FIG. 7 MAGNETO PERFORMANCE ON 0.93 OHM LOAD HYBRID CALIBRATION

SCALE 0.913

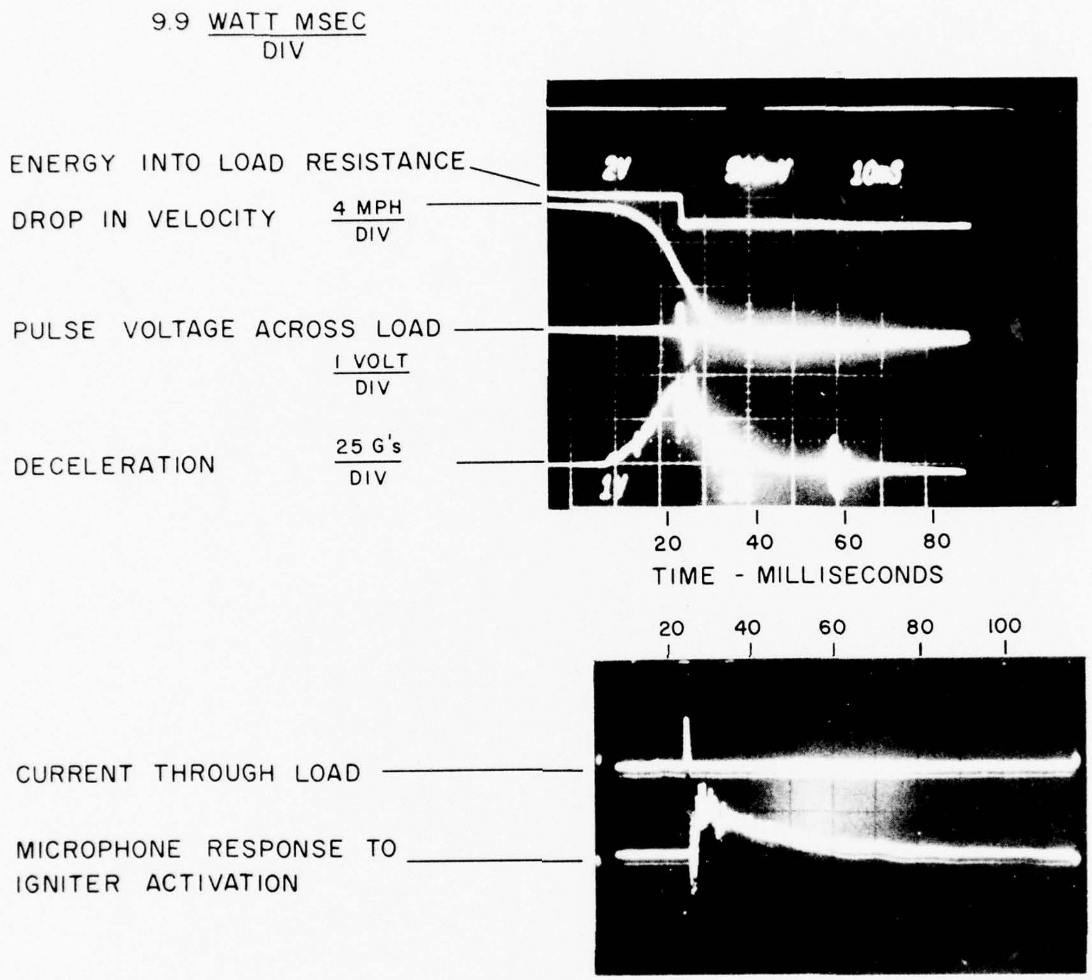


FIG. 8 MAGNETO PERFORMANCE ON 2.51 OHM LOAD

SCALE 0.913

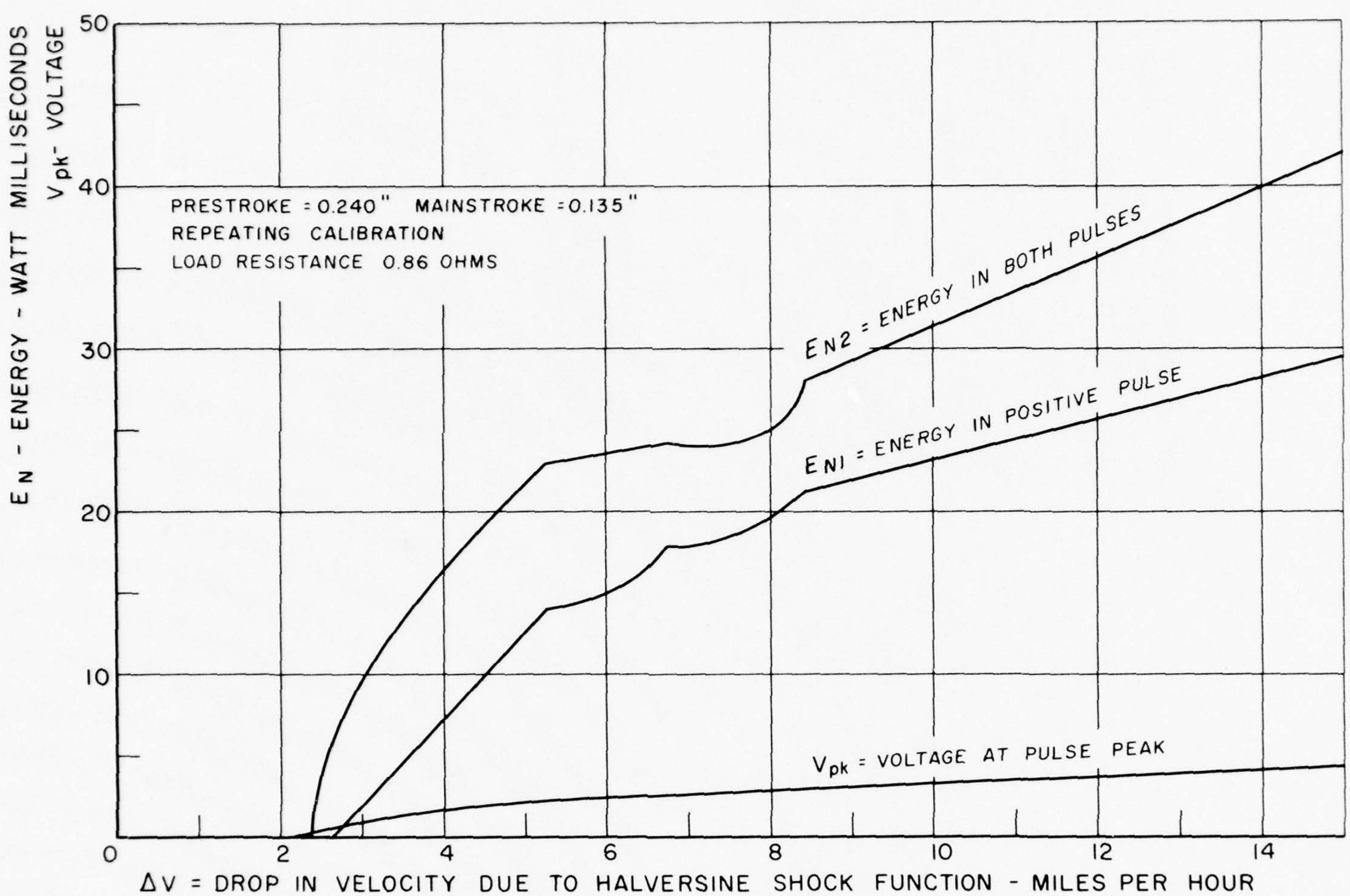


FIG. 9 TYPICAL PERFORMANCE OF SCALE 1.233 SHOCK MAGNETO

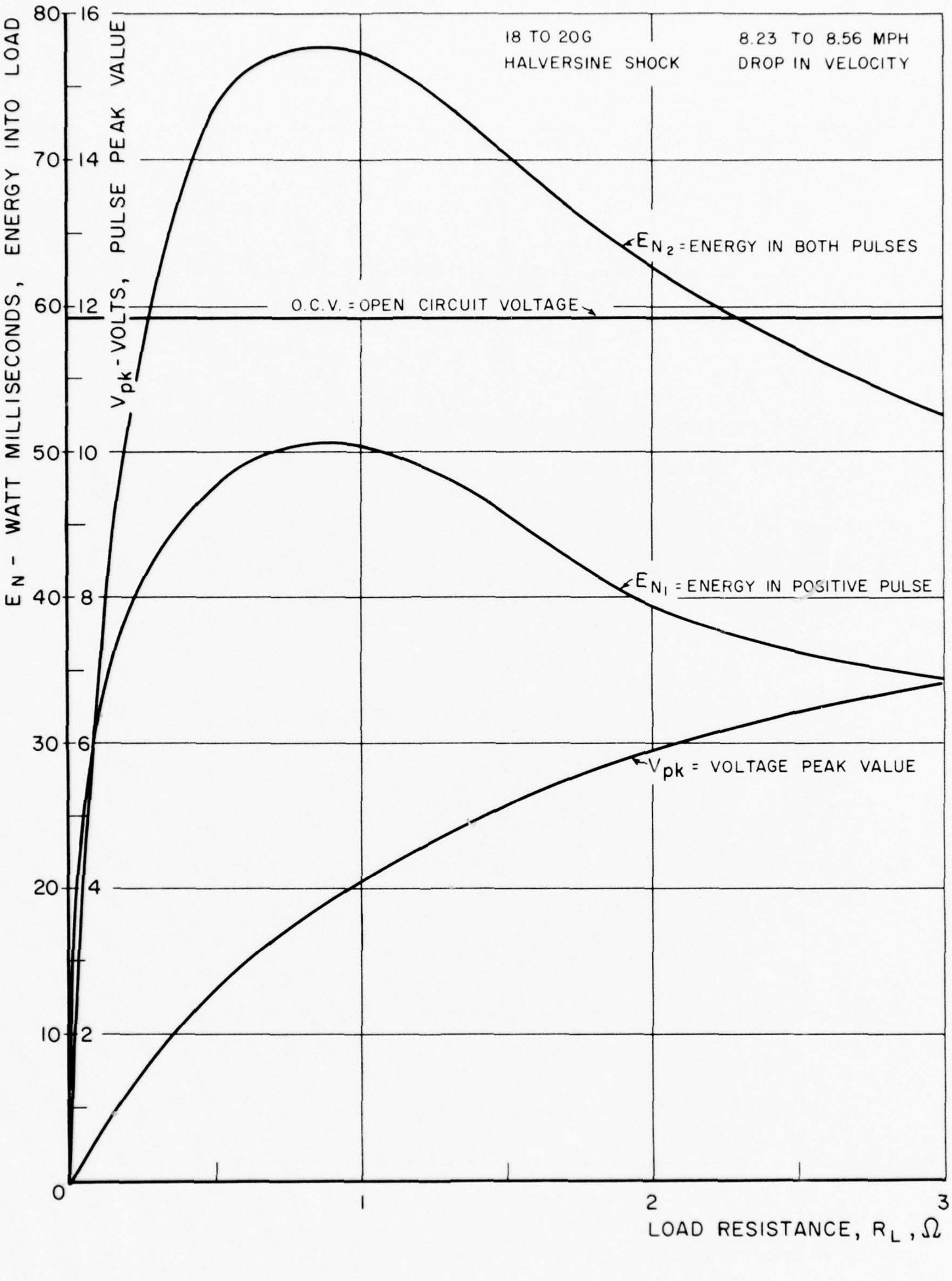


FIG. 10 PERFORMANCE OF SCALE 1.68 MAGNETO CALIBRATED FOR REPEATING OPERATION ON VARIABLE RESISTANCE LOADS

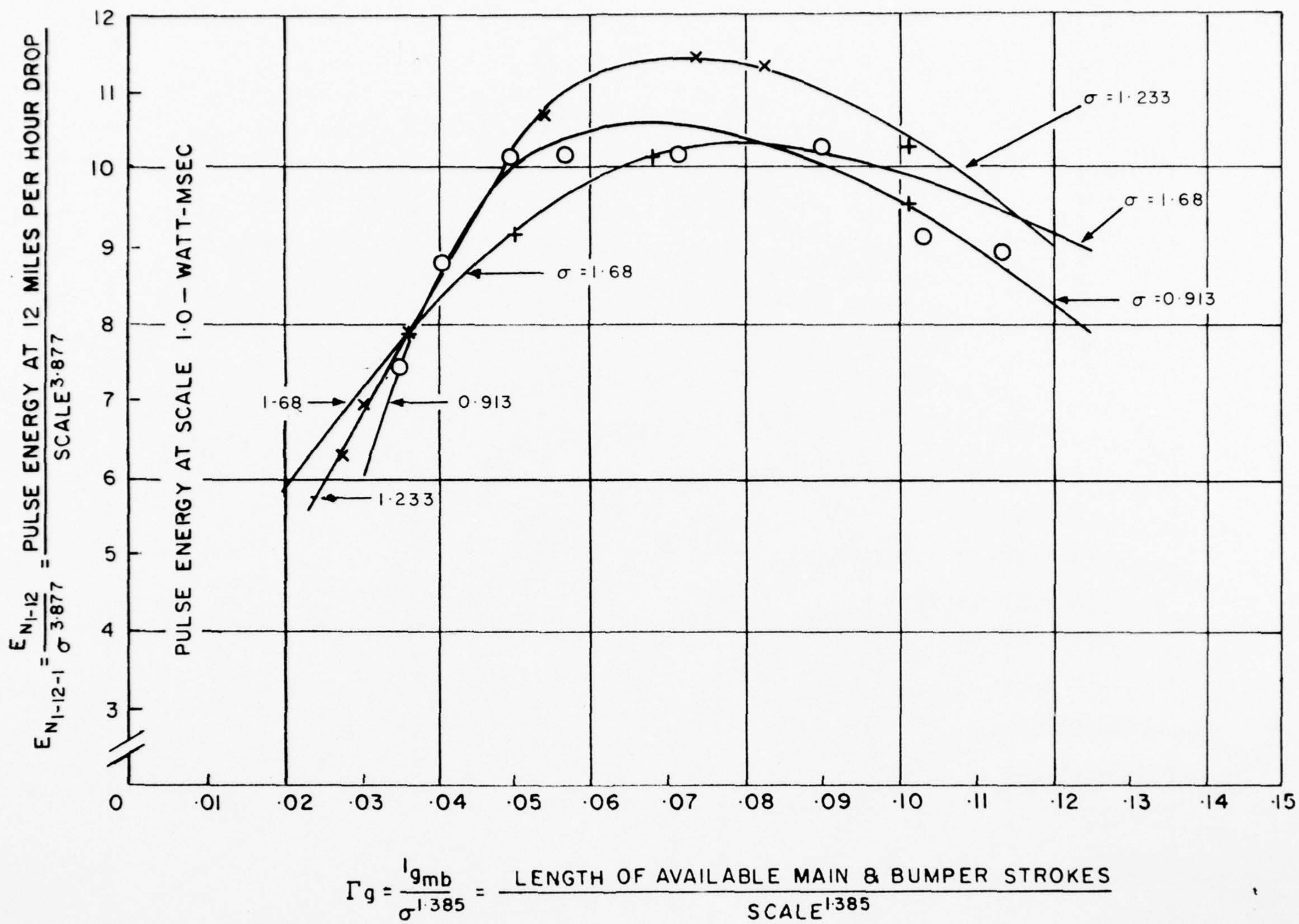


FIG. 11 OPTIMUM AVAILABLE STROKE FOR VARIOUS SCALES

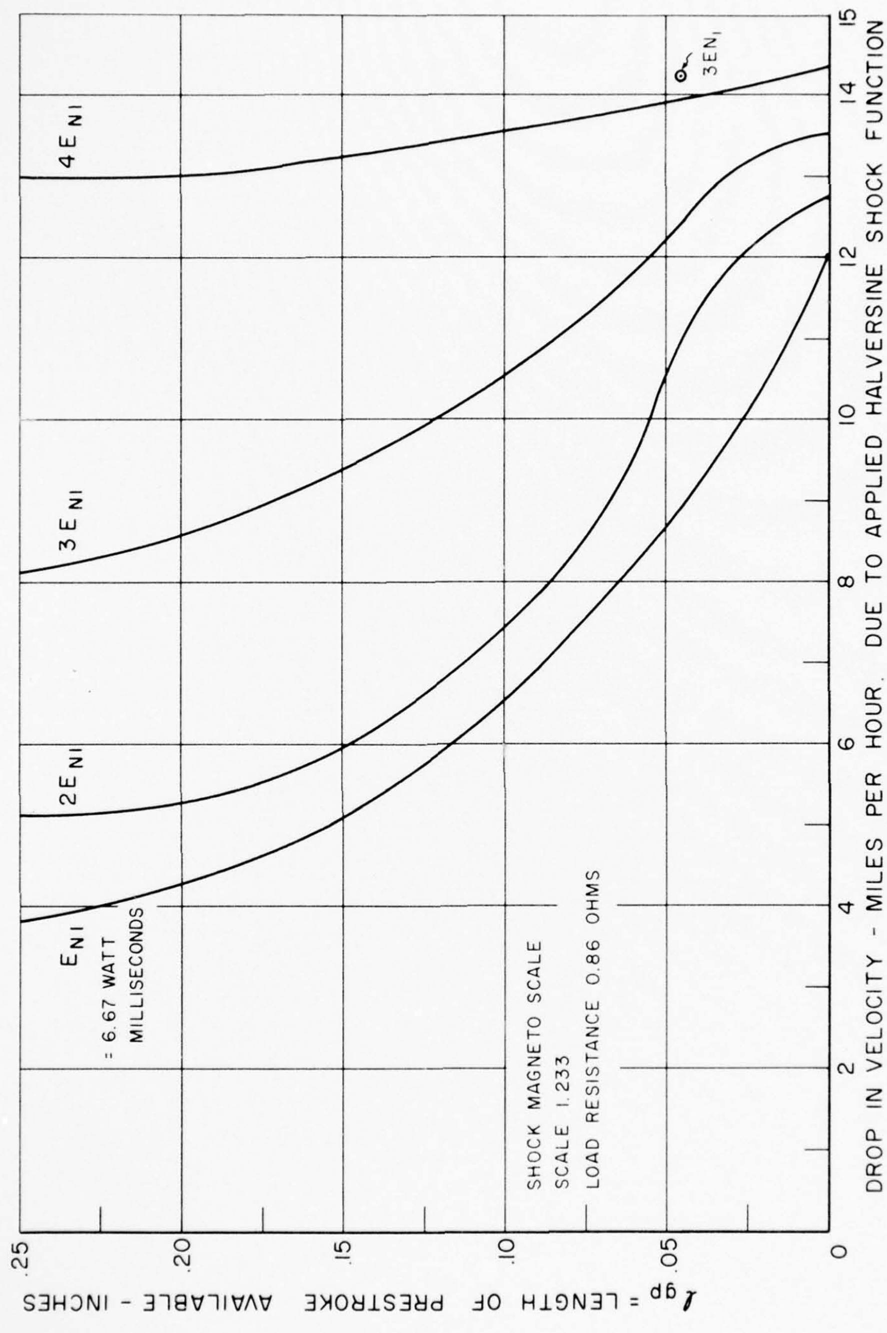


FIG. 12 EFFECT OF AVAILABLE PRESTROKE ON OUTPUT ENERGY CONTOURS

PROPOSED RESEARCH CAPABILITIES OF THE NAE CONVAIR 580

C.D. Hardwick

Flight Research Laboratory

National Aeronautical Establishment

This article is a brief outline of the research capabilities of the Convair 580 currently being planned and implemented. Since it is expected that the aircraft will be in service for at least ten years, over which time its specific research roles are bound to change, internal layout, computing system and aircraft instrumentation have been designed for as high a degree of flexibility as practicable.

RESEARCH ROLES

In addition to a number of new roles, the Convair 580 will be taking over the research functions which were carried out until recently by the North Star aircraft. The North Star was used primarily for aeromagnetic research using an extremely sensitive, oriented, optically pumped, cesium vapour magnetometer which was originally developed at NAE. The research projects based upon the use of this magnetometer break down as follows:

- Submarine detection
  - submarine signatures and signature recognition
  - study of geological noise backgrounds
  - development of a computer-based system (FACS) to compensate for magnetic effects associated with the motion of the aircraft, in order to allow the magnetometer to be used to its full sensitivity
- Long range geological surveys
  - construction of total field maps for Arctic areas of Canada from the Labrador sea to the North Pole
  - study of secular variations in the international model of the earth's magnetic field
  - measurement of magnetic dip angle and variation

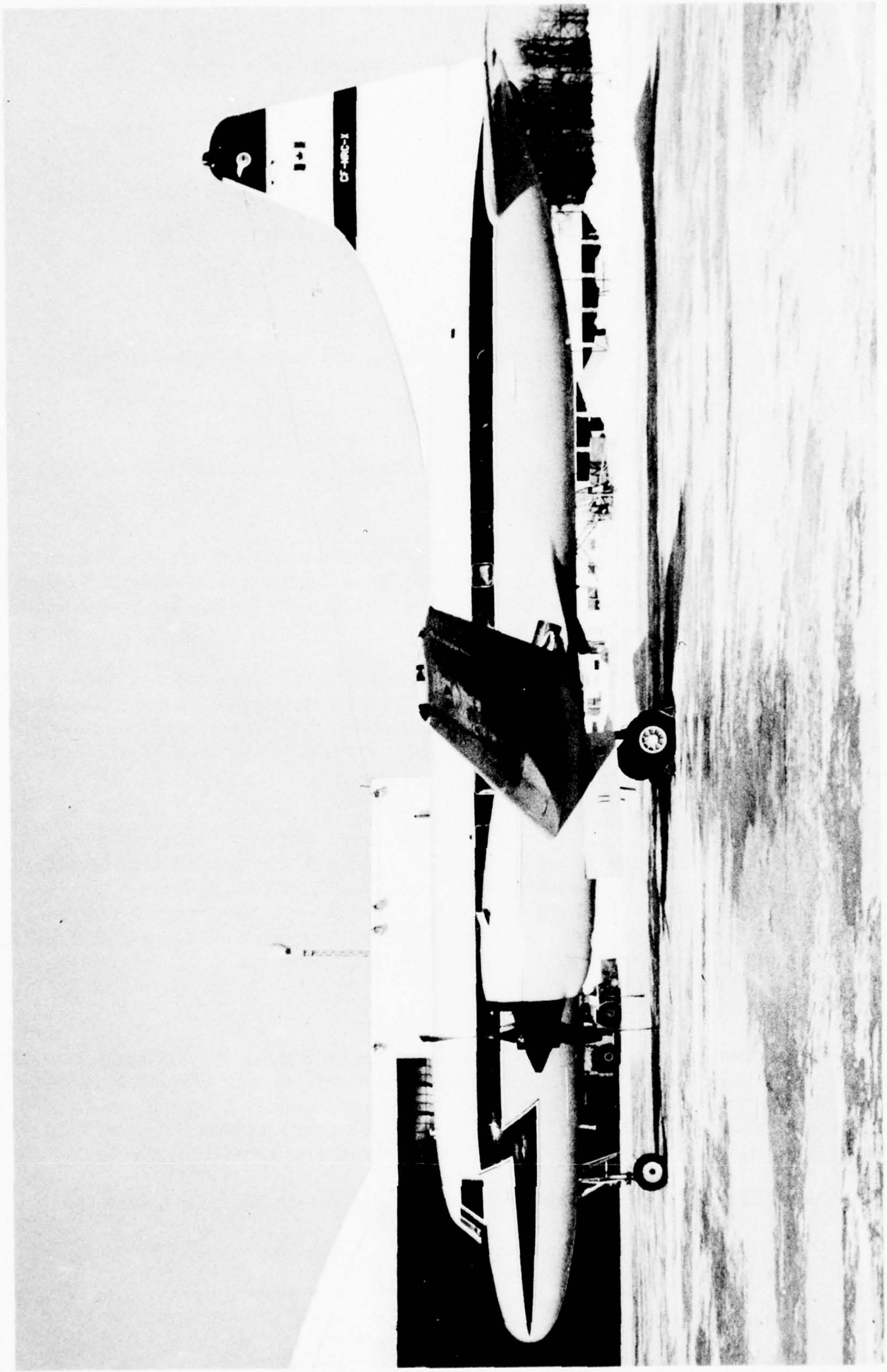
To support long range survey operations NAE developed a very low frequency (VLF) navigation system, all iterations of which were evaluated in the North Star. The system was also developed into a position reporting system that could be applied to remote object tracking, for which the North Star was the test bed.

Finally, the North Star was used for various short term projects such as airborne gravity measurement.

The new research functions of the Convair aircraft are as follows:

- Magnetic Detection
  - Array sensing. There will be one magnetometer at each wingtip and, ultimately, one at the top of the vertical fin.
  - Evaluation of a new generation, cryogenic, super-conducting magnetometer/gradiometer currently being developed.
  - Advanced target recognition techniques.

NAE NORTH STAR AEROMAGNETIC RESEARCH AIRCRAFT



NAE CONVAIR 580 RESEARCH AIRCRAFT

- Navigation Research
  - Comparitive evaluations of various long-range radio navigation methods, including satellite navigation.
  - Over-water tactical navigation display systems.
  - En route navigation displays.
- Satellite Communications
  - Remote tracking experiments using satellite up-link
  - Two-way data transmissions via AEROSAT.
- Acoustic Detection
  - Precision stores dropping capability will accommodate sonobuoys or active acoustic devices.
- Search and Rescue Beacon Evaluation
  - A search receiver will allow evaluation of new types of emergency beacons.
- General Purpose Digital Laboratory
  - The computing system (described subsequently) will make the aircraft a self-contained digital laboratory in the air, or on the ground either at NAE or, since the aircraft is completely self-supporting with respect to ground logistics, at remotely located airports.

In addition to the research functions outlined thus far, the Department of National Defence has requested time on the aircraft for advanced development of side-looking radar (SLAR) and for evaluation of electronic surveillance techniques. It appears that these two systems are compatible with the configuration of the aircraft and it is possible that provision will be made for installation of one or both systems.

SPECIFIC CAPABILITIES AND SYSTEMS

An appreciation of the general research capability of the aircraft may be obtained by looking at the individual systems presently being incorporated, without necessarily tying them to a particular field of research. It should also be kept in mind that we are talking about an aircraft whose cruising range at altitude is expected to be approximately 2,000 nautical miles at a TAS of 300 knots, with the same range at low level but with a TAS not exceeding 250 knots.

1. Work Station Layout

The interior layout of the aircraft has been done with an eye to maximum flexibility for future projects, with all but two stations set up on conventional tracking with quick disconnects for signal distribution and power to give complete and easy removability. A general purpose signal distribution system with a large amount of spare capacity allows work stations to be tied together via a main signal distribution station by means of easily programmed patchboards.

The nominal values of electrical power produced by the aircraft are as follows:

- 400 Hz — 40 KVA from each engine, plus 40 KVA from the APU (stinger)
- 28 VDC — 750 Amps

Some of the above DC will be used to provide:

- 60 Hz — 3000 VA (modularly expandable to 4250 VA)

All AC power sources will be phase-locked to the aircraft's rubidium frequency standard to ensure that there will be no low frequency beats in the instrumentation system. Each work station will be fitted with a comprehensive, three-channel intercom box. The work station layout is as follows, working aft:

Starboard side

- Spare
- Signal Distribution: general purpose instrumentation, signal patching and signal conditioning (Station non-removable)
- Analog Computing: 1 or 2 TR-20A's, depending on current requirements
- Magnetics/Spare.

Port Side

- Project Power: inverters, controls, circuit breakers, phaselock circuitry and load meters (Station non-removable)
- Navigator's Station: conventional navigation equipment, plus special radio receivers, audio system control and a special display system
- Digital: digital computer, peripheral devices and graphis display system
- Video Processing/Spare.

2. Signal Distribution/Conditioning

Signals from all aircraft transducers, sensors, and many avionics boxes will be brought to this station where they may be patched through to other work stations, to the signal conditioning interface for the digital system or to instrumentation such as oscilloscopes or the multi-channel analog chart recorder. Analog to digital conversion (32 channels, 12-bit), synchro-to-digital conversion and D-to-A (10 channels) conversion will be done at this station. In general, wherever possible, signal distribution will be by twisted pairs, one for each signal, and each pair individually shielded by means of a high efficiency, lightweight aliminum foil backed with mylar. This, plus extensive modification of the aircraft's power and grounding system, is expected to minimize ground loops and cross-talk problems that are all too frequently experienced in many aircraft.

The signal conditioning unit which will be part of this station will carry out gain scaling and special filtering, will give visual overscale warning and will provide automatic signal calibration.

3. Digital Computing System

3.1 Digital Processor and Peripherals

This will consist of:

- Central Processor, Interdata Model 732, 150K-byte memory with 750 nanosec memory cycle. It is essentially a 32-bit machine with special features such as hardware floating point.
- Two MTU's, one for in-flight data recording and the other for scratch pad functions, message logging and as a medium for data to be processed in the lab by other peripherals.
- 10 Megabyte Diabalo Disc consisting of two five-megabyte cartridges, one of which is removable.
- Paper Tape Reader
- NCR keyboard and hardcopy printer
- Video Display
- Special Interfaces for:
  - MAD counters
  - Flag/command bus (input/output discrete signals)
  - Navigation receivers
  - Digital altimeter
  - Display System
  - etc.

3.2 Software Operating Systems

a) Airborne

A special operating system, called 'OBOS' has been designed and is currently being programmed. Some of its features are as follows:

- Program modules run at five possible synchronous timing levels i.e. 32, 8, 2, 1 and 0.1 Hz. There is also a non-synchronous background level.
- Language: Interdata 32 bit assembler or Fortran V.
- Modules are brought into execution chain from disc by keyboard commands as required.
- Programs continuously on line are (typically)
  - multi-sensor navigation
  - data acquisition housekeeping
  - high resolution motion sensing
  - on-line magnetometer compensation

b) Ground Operating System

This will be a version of the Interdata 0S-32 Serial Task Operating System. It will be used for debugging, assembling and otherwise supporting the airborne operating system and/or its individual program modules. It will also be used for running programs on the ground that are physically much larger than could be supported by the airborne operating system.

4. Display System

There will be three video displays, one for the pilots, one each for the navigator and project digital operator. All three are capable of showing the same types of information, with each display operating essentially independently of the other with respect to content.

The types of information are:

- Alphanumeric — static or dynamic ("static" means computer generated information that is written on the display and remains essentially unaltered until the display is fully erased; "dynamic" information refers to elements within a static display, either characters, vectors or simple line-drawn objects, that change or move within the framework of the static display).

- Computer Graphics — static or dynamic (line or curve drawings and possibly grey scale vectors).

- Video Camera 1 — a camera looking down at 45° to the flight path with a 110° wide angle lens; used primarily for low level track recovery.

- Video Camera 2 — vertical down-looking camera with remote controlled 10:1 zoom lens; used for measuring drift, offset from targets, etc.

- Weather radar — cloud and ground mapping pictures.

- Video tape — playback of any display scene that may have been recorded.

For any display position, graphics and/or alphanumerics can be overlaid on a video camera scene or on the weather radar. Alphanumerics and graphics will be produced by combination of two alphanumeric generators and two Hughes Conographic vector generators.

Organization of the display is on a page basis, the specifications for which will be kept on disc. The pilots or navigator can call for a particular page of display by means of a small alphanumeric keyboard with a limited command set; project display pages will be called via a full computer-graphics keyboard. Pages can contain both static and dynamic information and an operator can interact with a page via his keyboard or via a two-axis joystick. (The latter could, for example, slew a "bug" about on the screen, expand range rings, or move a cursor to select a particular program for running from a list of programs. etc.)

A block diagram of the computing and display system is shown in Figure 1.

5. Aircraft Instrumentation

The following signals will be available to the computing system via high-quality transducers:

- Accelerations
- Angular rates
- Attitude
- Wingtip vertical accelerations
- Control positions
- Air data (from each wingtip)
  - Pitot pressure
  - Temperature
  - Static pressure from a boom-mounted swivelling static source
  - Boom-mounted angle-of-attack and sideslip transducers
  - Altitude rate

  (Note: Except when wingtip differential data are required, only one air data boom will be used.)

- Heading reference (two Sperry C-12 systems)
- Doppler body-axis velocities
- Radio altimeter
- DME signals
- ADF bearings
- VOR/localizer and glide slope

6. Navigation System

The following sources of position fixing information will be available to the computing system:

- VLF
- Omega
- Loran-C
- Double DME (Area Nav.)
- VOR and ADF bearings
- Heading Reference System
- NAVSAT (Global Positioning System).

A sextant system will be used to make corrections to the heading gyros during Arctic operations. Very short term velocity information will be supplied from the accelerometers via appropriate axis transformations.

All of the above information, suitably weighted for validity etc, will be combined to form an optimum solution for position and velocity in an algorithm that estimates the errors in each data source using Kalman filtering techniques. For evaluation purposes, however, the raw data from each navigation sensor will be recorded to assess the performance of a particular system and, if required, certain individual solutions can be computed on-line.

7. Photography (Non-video)

A standard Automax 35 mm camera will be mounted on a removable belly hatch door to look vertically downwards. It will be controlled by the computer or by discrete signals from the pilots or other crew members. An unmodified door will be in place when the camera is not required.

Some design consideration has been given to mounting a laser to use the same hatch door; this would be used for precision altimetry as required for gravity experiments.

8. Stores Dropping System

A spring-activated, pressurization-assisted launcher for standard 6-in. sonobuoys and 3-in. smoke markers has been designed. Drop trajectory can be pre-computed based on aircraft flight data and on wind at altitude, to give fairly good accuracy. A microswitch to signal positive release will give a "clear" indication to the pilots and will also allow corrections to be made to pre-computed drop locations. The accuracy of any drop will ultimately be checkable by means of the video display system.

IN SUMMARY

Most of the systems outlined will be installed in the first phase of the modification, which should be completed in 1978. Such items as the tail magnetometer and the stores dropping mechanism will be left for a second phase. By the second phase, it is anticipated that user needs will be more clearly defined than at present and various new capabilities will be incorporated. However, it is hoped that the flexibility incorporated in the Phase 1 design will allow additional capabilities to be built-in relatively easily without major structural rework.

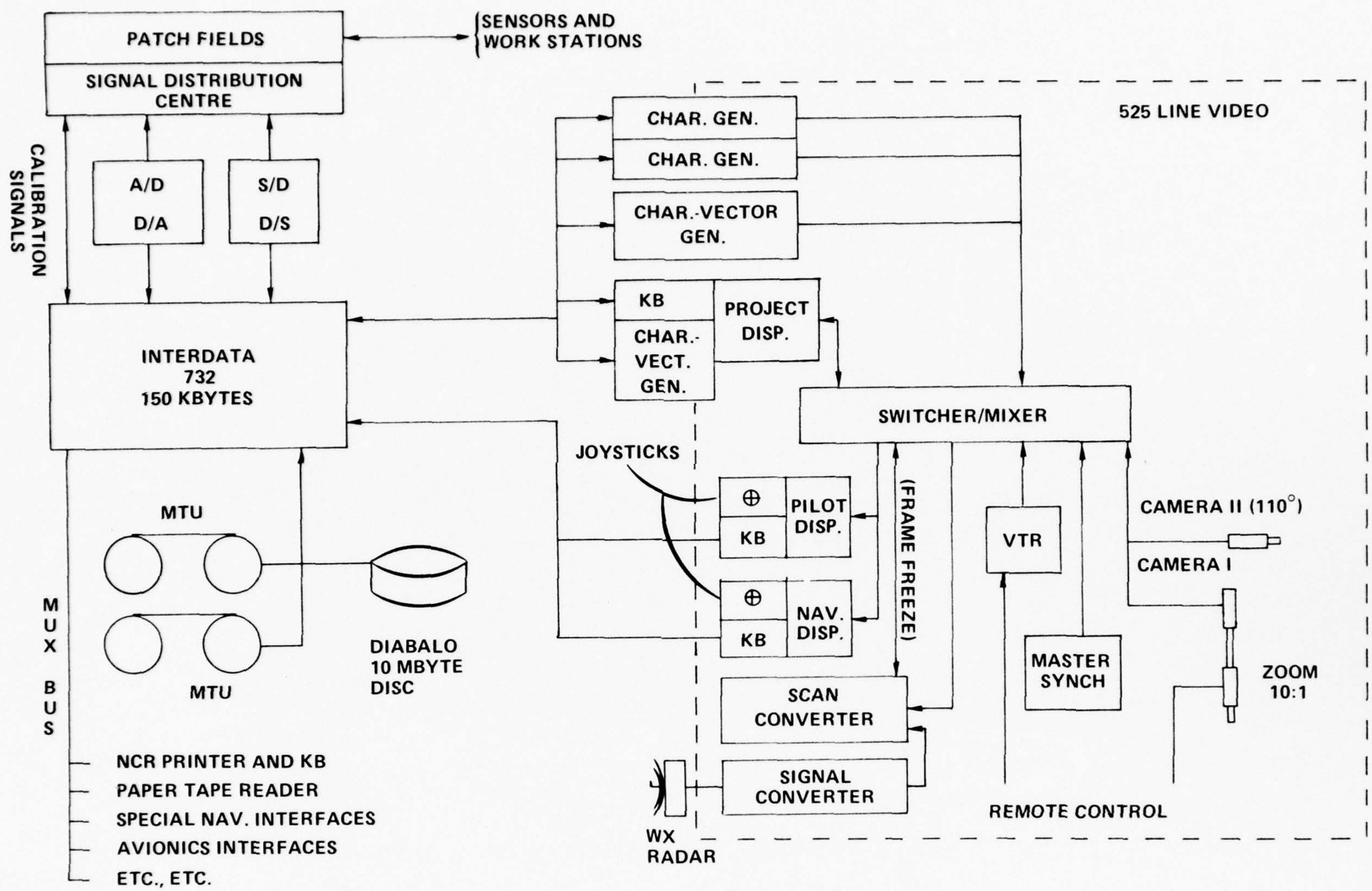


FIG. 1 NAE CONVAIR 580 COMPUTING AND DISPLAY SYSTEM

CURRENT PROJECTS

Much of the work in progress in the laboratories of the National Aeronautical Establishment and the Division of Mechanical Engineering includes calibrations, routine analyses and the testing of proprietary products; in addition, a substantial volume of the work is devoted to applied research or investigations carried out under contract and on behalf of private industrial companies.

None of this work is reported in the following pages.

ANALYSIS LABORATORY

AVAILABLE FACILITIES

This laboratory has analysis and simulation facilities available on an open-shop basis. Enquiries are especially encouraged for projects that may utilize the facilities in a novel and/or particularly effective manner. Such projects are given priority and are fully supported with assistance from laboratory personnel. The facilities are especially suited to system design studies and scientific data processing. Information is available upon request.

EQUIPMENT

1. An Electronic Associates 690 HYBRID COMPUTER consisting of the following:
   (a) PACER 100 digital computer
   - 32 K memory
   - card reader
   - high speed printer
   - disc
   - digital plotter

   (b) Two EAI 680 analogue computer consoles
   - 200 amplifiers including 60 integrators
   - 100 digitally set attenuators
   - non-linear elements
   - x-y pen recorders
   - strip chart recorders
   - large screen oscilloscope

   (c) EAI 693 interface
   - 24 digital-to-analogue converters
   - 48 analogue-to-digital converters
   - interrupts, sense lines, control lines

2. Hewlett Packard Model 3960 FM instrumentation tape recorder. IRIG standard, 4-track, 1/4-inch tape. Speeds: 15/16, 3-3/4 and 15 inches per second.

APPLICATIONS STUDIES

In collaboration with United Aircraft of Canada Ltd., a hybrid computer model of an advanced turbo-fan engine is being put together in order to investigate the expected performance of the engine and its control system.

In collaboration with the Railway Laboratory, a pilot hybrid computer model of the NRC roller rig for railway vehicle testing is being built as an aid in the design of the roller rig and its controls.

In collaboration with the British Gas Council, TransCanada Pipelines Ltd. and G.F. Crate Ltd., a study of the station controls for the St. Fergus terminal gas compressor station, location on the North Sea coast, is being undertaken.

In collaboration with the Control Systems and Human Engineering Laboratory and the Quebec Iron and Titanium Co., interactive computer model of an iron smelter is being developed to study scheduling of cranes and tracked vehicles and to improve materials handling in the smelter.

In collaboration with Aviation Electric Ltd., modelling work is underway in support of their advanced control concepts for both the small business jet engine and the helicopter engine. At present, a validation of a detailed model of a twin engine helicopter model is complete.

In collaboration with the Control Systems and Human Engineering Laboratory and the International Nickel Co., Ontario Division, an interactive computer model of a copper-nickel smelter is being developed to study material handling and scheduling in the plant.

In collaboration with the Engine Laboratory, a data reduction program has been put together for the hybrid computer which accepts tape recorded transducer data gathered during transient engine tests of the J85 program. The program is currently being used to process data from the test program.

In collaboration with R.L. Crain Ltd., an interactive order streaming program for a print shop is being developed for use by the press-co-ordinators.

In collaboration with Canadian Westinghouse Ltd. and G.F. Crate Ltd., a study is being made of the fuel controller requirements for a new family of 35,000 HP gas turbines. A hybrid computer model is being assembled to be used in the development.

In collaboration with Kendall Consultants Ltd. and SPAR Aerospace Products Ltd., a hybrid computer model of the remote manipulator arm being designed for the space shuttle is being assembled. The model is to include all allowable motions in three dimensions as well as arm flexibility effects.

In collaboration with Davis, Eryou and Associates and the Low Speed Aerodynamics Laboratory of NAE, a hybrid computer data analysis package has been assembled to reduce data obtained from field trials of aerodynamic drag reducing devices on trucks.

APPLICATIONS STUDIES BY OTHERS

Kendall Consultants Ltd., under contract to SPAR Aerospace Products Ltd., have assembled a hybrid computer model of the proposed joint design of the remote manipulator arm for the space shuttle. Two joints have been modelled, and the arm flexibility effects on the design have been evaluated.

CONTROL SYSTEMS AND HUMAN ENGINEERING LABORATORY

INDUSTRIAL CONTROL PROBLEMS

Industrial systems and agricultural applications of fluidic circuits.

Fluid sensor and control component research and development.

Interactive computer modelling applied to operations scheduling of large scale industrial plants and processes.

Development of CAMAC instrumentation for industrial control applications.

Engineering support to specific firms for the implementation of schemes for control and mechanization.

HUMAN ENGINEERING — BEHAVIOURAL STUDIES

Investigation of the control characteristics of the human operator and the basic phenomena underlying tracking performance.

Investigation of the nature of sensory interaction in human perceptual-motor performance.

Investigation of the factors involved in the presentation and processing of information, particularly in relation to simulator design.

HUMAN ENGINEERING — MEDICAL AND SURGICAL

Investigation of the implementation of feedback control in living organisms with particular reference to the control of temperature and pressure in the spinal cord.

Development of heat exchangers for localized cooling of the spinal cord.

Measurement in-vivo of the mechanical impedance characteristics of skin and healed wounds.

Development of models of tissue sections, organs, and whole organisms.

Development of stereo-taxic and allied apparatus for neurosurgical procedures.

PATTERN RECOGNITION AND IMAGE PROCESSING

Investigation of the fundamentals of pattern recognition and their application to identification and classification problems with particular reference to image enhancement and computer analysis of human chromosome material from electron micrographs.

ENGINE LABORATORY

HOSPITAL AIR BED

A hospital air bed designed and built by NRC has been delivered to the Hotel Dieu Hospital in Kingston, Ontario for clinical evaluations of treatment of burn patients. The function and performance specifications of the bed were devised in collaboration with Canadian medical authorities to satisfy Canadian needs.

A second air bed was purchased in England by the Victoria Hospital in London, Ontario, and was adapted by NRC to meet Ontario Hydro requirements.

Several modifications were made to the NRC air bed as a result of the early testing experience. Both beds are being used very successfully for clinical evaluation.

GAS TURBINE OPERATIONS

An investigation of aircraft gas turbine engine operating characteristics is being conducted in conjunction with the Canadian Forces.

Assistance has been given to the Canadian Forces in the development of an inlet protective system for sea-borne gas turbines operating in icing environments.

Prototype instrumentation for an in-flight thrust meter has been verified on a test-bed installed turbojet engine.

DUCTED FAN AEROACOUSTICS

A 12-inch diameter ducted fan model has been tested aerodynamically for the purpose of making performance comparisons between a standard 19-bladed stator and a 19-bladed stator with stepped leading edges. Comparative noise studies of the same configurations in an acoustically treated test cell have recently also been completed.

These experiments are made by the Engine Laboratory in co-operation with the Division of Applied Physics with the intent of exploring special noise reducing features in ducted fan design.

ENGINE COOLING SYSTEM PERFORMANCE

In collaboration with Canadian industry an experimental study is being made of automotive cooling fan performance with the fan in its actual engine bay environment and subject to normal ram air conditions. The study involves both road and wind tunnel tests at full scale under hot and cold radiator conditions. The test vehicle is typical of an intermediate size North American passenger car, and along with considerable in-vehicle instrumentation, is being provided by the industry for test purposes.

ROTOR DYANMICS

An experimental rig is being constructed to investigate techniques for improved vibration signal diagnosis from rotating machinery under a variety of operating and support conditions.

A review of the published results of analytical and experimental investigations of the dynamic stiffness and damping coefficients of a rotor supported in fluid film bearings is being prepared.

The operating range of the laboratory's torsional vibration transducer calibrator is being extended to meet new requirements from industry.

AIR CUSHION VEHICLES

The first CASPAR program, on the Multicell skirt has been completed. A report on this program has been issued.

An analytical study of ACV drag overland is continuing. Advances in the theory have been formulated, and an experimental program is in progress, to explore the validity of these theories and provide numerical values for the coefficients proposed.

An associated study of skirt element structural stability and response to transient disturbances during forward motion is proceeding.

A new (HDL) type skirt system has been built onto research vehicle HEX-1B, and this test program is in progress.

Research vehicle HEX-3 is being completely rebuilt to the HEX-4 configuration. It will be used for high-speed skirt-wear experiments, with particular reference to on-road A.C. assisted transports, and later for over-snow drag tests related to icebreaking problems. Special instrumentation for this work is being incorporated.

HYDROSTATIC BEARINGS

The design and testing of a hydrostatic bearing support system for the railroad roller test rig is in progress.

AEROACOUSTICS

A study of the noise characteristics of centrifugal blowers is in progress. An existing laboratory centrifugal fan has been tested to investigate the relation between flow characteristics and noise generation and to determine appropriate test procedures. The effects of certain changes in casing geometry on the noise generated by a commercial blower have been investigated.

AIR BEARINGS

Experimental and analytical work on air lubricated bearings and seals is continuing. Attention is being focused on aerostatic thrust bearings with one compliant surface.

INDUSTRIAL AERODYNAMICS

In conjunction with the Gas Dynamics Laboratory further studies are being carried out on the internal gas flow distributions in an industrial furnace.

HYBRID DRIVE VEHICLE SIMULATION

An all-digital computer simulation of hybrid drive vehicles is being developed. Initially, a heat engine-hydraulic drive system will be modelled and verified against a prototype system installed in the Fuels and Lubricants Laboratory.

NRC — PRATT & WHITNEY HIGHLY LOADED TURBINE

The test cell is in an advanced state of preparation and installation of test fixtures is underway. A data acquisition and reduction system has been ordered and will be used on this experiment.

FLIGHT RESEARCH LABORATORY

AIRBORNE MAGNETICS PROGRAM

Experimental and theoretical studies relating to the further development of airborne magnetometer equipment and its application to submarine detection and geological survey, are currently in progress. The North Star flying laboratory has now been retired but analysis of magnetic data taken over east, west and Arctic coasts of Canada will continue for some time to come. Studies are continuing in very low frequency (VLF) and other navigation methods to support long range geophysical surveys. A Convair 580 aircraft to replace the North Star is currently being equipped with new magnetometer and computing systems.

INVESTIGATION OF PROBLEMS ASSOCIATED WITH V/STOL AIRCRAFT OPERATIONS

The Laboratory's Bell 205A1 variable stability helicopter is being employed in programs to investigate terminal area operational problems which are most severe for or peculiar to aircraft capable of low approach speeds. The 205, which is capable of measuring and recording the magnitude of the three components of motion of the atmosphere through which it flies, is employing this capability in a program of terminal area wind and turbulence documentation at the Rockcliffe STOLport. In a related program the 205 is being configured to simulate the flight characteristics and handling qualities of a powered-lift STOL transport aircraft. The effects of severe turbulence and strong wind shears on the approach handling qualities and operational envelope of such an aircraft are being evaluated by flying the simulated vehicle through naturally occurring atmospheric disturbances.

INVESTIGATION OF ATMOSPHERIC TURBULENCE

A T-33 aircraft, equipped to measure wind gust velocities, air temperature, wind speed, and other parameters of interest in turbulence research, is used for measurements at very low altitude, in clear air above the tropopause, in the neighbourhood of mountain wave activity, and near storms. Records are obtained on magnetic tape to facilitate data analysis. The aircraft also participates in co-operative experiments with other research agencies, in particular, the Summer Cumulus Investigation (see below). A second T-33 aircraft is used in a supporting role for these and other projects.

AIRCRAFT OPERATIONS

The Flight Recorder Playback Centre is engaged in the recovery and analysis of information from the various flight data recorders and cockpit voice recorders used on Canadian military and civil transport aircraft. The military systems are being monitored on a routine basis. Civil aircraft recorders are being replayed to investigate incidents or accidents at the request of the Ministry of Transport. Technical assistance is being provided during incident and accident investigations and relevant aircraft operational problems studied.

INDUSTRIAL ASSISTANCE

Assistance is given to aircraft manufacturers and other companies requiring the use of specialized flight test equipment or techniques.

INVESTIGATION OF SPRAY DROPLET RELEASE FROM AIRCRAFT

Theoretical and experimental studies of spray droplet formation from a high speed rotating disc have been conducted. Flight experiments utilize a Harvard aircraft modified to carry external spray tanks. Automatic flying spot droplet and particle analysis equipment is in operation for processing samples obtained in the laboratory and in the field by various agencies. The equipment has potentialities for the analysis of many unusual configurations provided that these may be photographed with sufficient contrast.

AUTOMOBILE CRASH DETECTOR

There is a need for a sensing device to activate automobile passenger restraint systems in incipient crash situations. Investigations are in progress to determine the applicability of C.P.I. technology to this problem.

SUMMER CUMULUS INVESTIGATION

At the request of the Department of the Environment flight studies of Cumulus cloud formations over Quebec and Ontario were instituted during the Summer of 1974. Instrumented T-33 and Twin Otter aircraft with a Beech 18 are being used to determine the properties of Cumulus clouds which extend appreciably above the freezing level. These measurements are being made to assess the feasibility of inducing precipitation over forest fire areas by seeding large cumulus formations. During 1975 a variety of cloud physics instruments were added to the Twin Otter, and special pods for burning silver iodide flares were attached beneath the wing of the T-33 turbulence research aircraft. The effects of seeding on the microstructure of individual cumulus clouds were studied in the Yellowknife area during the summers of 1975 and 1976. This project is planned to continue for several years.

FUELS AND LUBRICANTS LABORATORY

COMBUSTION RESEARCH

Experiments on fuel spray evaporation.

Investigation of handling and combustion problems involved in using hydrogen as a fuel for mobile prime movers.

Study of possible methods for destruction of oxides of nitrogen in engine exhaust gas.

Evaluation of the use of mixtures of methane and carbon dioxide as automobile fuels.

EXTENSION AND DEVELOPMENT OF LABORATORY EVALUATION

Development of new laboratory procedures for the determination of the load carrying capacity of hypoid gear oils under high speed conditions and under low speed high torque conditions.

Evaluation of filter/coalescer elements for aviation turbine fuels.

Evaluation of longlife filter/coalescer elements from aviation turbine fuel service.

PERFORMANCE ASPECTS OF FUELS, OILS, GREASES, AND BRAKE FLUID

Co-operative investigation covering used oil analysis and inspection of engines from Ottawa Transportation Commission buses to establish realistic oil and filter change periods.

Investigation of laboratory methods for predicting flow properties of engine and gear oils under low temperature operating conditions.

Investigation of laboratory methods for predicting low temperature flow properties of diesel and heating fuels and assessment of their suitability.

Co-operative investigation covering test procedure for the evaluation of thermal oxidation stability of hypoid gear lubricants.

Evaluation of performance of experimental engine lubricants to determine their effect on ring sticking, wear, and accumulation of deposits under high speed, supercharged conditions.

Development of a laboratory method for the evaluation of oil performance in air-cooled two-stroke engines.

Investigation of the electrostatic charging tendency of distillate fuels.

Evaluation of static dissipator additives for distillate fuels.

Evaluation of properties of re-refined oils and surveys of problems in the oil re-refining industry.

Investigation of the use of anti-icing additive in aviation gasoline.

MISCELLANEOUS STUDIES

The preparation and cataloguing of infra-red spectra of compounds related to fuels, lubricants, and associated products.

The application of Atomic Absorption spectroscopy to the determination of metals in petroleum products.

Investigation of the stability of highly compressed fuel gases.

Analytical techniques for analysis of engine exhaust emissions.

Participation in the Canadian (CGSB), American (ASTM) and Internation (ISO) bodies to develop standards for petroleum products and lubricants.

The design and development of an internal combustion engine/hydraulic transmission hybrid power plant for the energy conserving car.

Further developments of specialized pressure transducers for engine health diagnosis and the development of diagnostic techniques.

GAS DYNAMICS LABORATORY

V/STOL PROPULSION SYSTEMS

A general study of V/STOL propulsion system methods with particular reference to requirements of economy and safety.

INTERNAL AERODYNAMICS OF DUCTS, DIFFUSERS AND NOZZLES

An experimental study of the internal aerodynamics of ducts, bends, diffusers and nozzles with particular reference to the effect of entry flow distortion in geometries involving changes of cross-sectional area, shape, and axial direction.

SHOCK PRODUCED PLASMA STUDIES

A general theoretical and experimental investigation of the production of high temperature plasma by means of shock waves generated by electromagnetic and gasdynamic means, and the development of diagnostic techniques suitable for a variety of shock geometries and the study of physical properties of such plasmas.

NON-DESTRUCTIVE SURFACE FLAW DETECTION IN HOT STEEL BILLETS

An eddy-current surface flaw detector is being developed, using a special coil system by which a three-phase modulated R.F. signal is being electrically rotated round the billet at a rate given by the modulation frequency. The system displays the angular position of the flaw on a polar oscilloscope sweep or numerically, while the signal amplitude represents the depth of the flaw.

HIGH PRESSURE LIQUID JETS

High speed water jets generated by pressures in the range of 1000 to 60,000 psi can be used for cutting a wide variety of materials, e.g. paper, lumber, plastics, meat, leather, etc., and for cleaning surfaces such as masonry, rocks, tubular heat exchangers, etc. Nozzle sizes, depending on the application, are in the range from 0.002 to 0.15 in. diameter. A technique for manufacturing small nozzles in the range 0.002 to 0.015 has been developed using standard sapphire jewels available from industry. Larger orifices are manufactured and polished using standard shop procedures.

At present, the following investigations are active in the laboratory:

1. Intensive development of a rotating seal designed and developed in the laboratory. It appears to have great potential, especially for industrial cleaning, quarying and possibly for drilling operations.

2. Experiments on the fracturing of rocks using continuous and cavitating jets.

3. Experiments for clearing ice off runways and for cutting through thick ice ridges.

4. Experiments on the production of intermittent jets with high stagnation pressures.

HEAT TRANSFER STUDIES

Initial development of a temperature control thermosiphon for an electronic package has been successfully concluded. Life testing of this device has commenced.

COMPUTATIONAL FLUID DYNAMICS

To support the experimental work, numerical simulations are being developed in three areas.

Single-pulse jets from vertically-accelerated liquid-filled rotating cones. This is a two-dimensional, axisymmetric, unsteady, incompressible flow problem with a free surface, where the liquid is subjected to large body accelerations.

Fluid dynamics of laser-produced plasmas. The phenomena are considered as two-dimensional, axisymmetric, unsteady, compressible flow problems in which real gas behaviour is considered. The approach, which uses Lagrangian formulation, has been used to calculate two cases:

(a) The fluid dynamics of a laser breakdown plasma, with the objective of explaining the mechanism of beam re-entry into the plasma when beam intensity is reduced.

(b) The interaction of a CO_2 laser beam with magnetically confined plasmas. This major problem is currently being studied numerically as part of a co-operative effort with the Aerospace Research Laboratory of the University of Washington.

Shock dynamics and fluid dynamics resulting from synchronized spark discharges on the axis and discharges on the perimeter of a cylindrical vessel containing hydrogen, to achieve high gas temperatures on the axis of the vessel.

GAS TURBINE BLADING STUDIES

A program on the theoretical and experimental study of the performance of highly loaded gas turbine blading has been undertaken as a collaborative program with industry and universities.

INDUSTRIAL PROCESS, APPARATUS, AND INSTRUMENTATION

There is an appreciable effort, on a continuing basis, directed towards industrial assistance. This work is of an extremely varied nature and, in general, requires the special facilities and capabilities available in the laboratory.

Current co-operative projects with manufacturers and users include:

(a) Flow problems associated with industrial gas turbine exhaust systems (Foster Wheeler).
(b) Combustion studies for industrial gas turbine applications (Westinghouse and Rolls-Royce).
(c) Application of thermosiphon as an energy conserving device in industrial applications (Dept. of Agriculture, Ministry of Transport and Farinon Electric).
(d) Scaled model studies on steel and copper converters to establish relative performance and ceramic liner deterioration rates (Canadian Liquid Air and Noranda).
(e) High pressure water jet applications in industry (High Pressure Systems Ltd.).
(f) Power turbine nozzle vane studies (Westinghouse).
(g) Scaled model studies to establish the performance of complex industrial flue systems with a view to establishing specific design and performance criteria.

HIGH SPEED AERODYNAMICS LABORATORY

CONTROL OF TURBULENT BOUNDARY LAYER IN A THREE-DIMENSIONAL SHOCK WAVE/BOUNDARY LAYER INTERACTION

The investigation of the three-dimensional interaction between a swept shock wave and a turbulent boundary layer along a flat wall at freestream Mach number of 2 and 4 in the 5-in. × 5-in. blowdown wind tunnel has been completed. Some parts of the work were reported at the AGARD Specialists meeting on 'Flow Separation' at Göttingen, W. Germany, May 1975, and have been published in the Conference Proceedings, AGARD CP-168. A fuller report is now available as NRC LR-592, July 1976.

SETTLING CHAMBER STUDY IN 5-IN. × 5-IN. WIND TUNNEL

Revisions to the settling chamber of the 5-ft. × 5-ft. wind tunnel are under consideration to improve the flow distribution and to decrease the level of pressure fluctuation at the entry to the stilling section. Model tests are to be conducted in the NAE pilot facility, initially to determine the effect of increasing the resistivity of the second porous (disked) baffle in the wide angle diffuser ahead of the stilling section.

TWO-DIMENSIONAL TRANSONIC FLOW STUDIES

Efficient computer programs based on finite difference procedures are available for the design of supercritical airfoils and for the analysis of supercritical flow. The possibility of using finite element methods are being explored with the aim of extending into three-dimensional flow cases.

HIGH REYNOLDS NUMBER PIPE FLOW

This investigation is carried out at the request of and in co-operation with Laval University, Quebec.

The object is to obtain turbulent skin friction data at very high Reynolds number (Re_d up to 20×10^6) in an 8-in. pipe. The investigations to date include calibration of a range of Preston and razor blade surface pitot tubes and mean velocity traverses. Turbulence and noise measurements are also being considered. Analysis of the Preston tube calibration data has been carried out and the results agree well with semi-empirical theory based on the logarithmic wall law.

A floating element balance has recently been supplied by Laval University and will be installed for direct skin friction measurements.

THEORETICAL AND EXPERIMENTAL STUDY OF JET NOISE

Further investigations of internal noise in a low speed jet are in progress. More detailed studies of the interaction of the transmitted sound with the jet flow and some statistical investigation of the multiple wave scattering by the turbulent eddies will be carried out. Some experiments on co-axial jets have been performed and measurements of pressure fluctuations in the turbulent shear layer has been undertaken.

Wave-like large scale eddies have been shown to be the basic characteristic of free turbulent shear flows. For circular jets, measurements of the wave development have been made for the axisymmetric mode of propagation. Recent experiments show that the jet can also support wave propagation in helical modes. Some detail measurements have been performed. A report on the helical mode study was presented at the 10th ICAS Congress in Ottawa, October 1976.

THREE-DIMENSIONAL WALL INTERFERENCE EFFECTS

The measurements on three geometrically similar aircraft models by ONERA are used to analyze lift interference effects in the solid and perforated wall test sections of the NAE 5-ft. × 5-ft. test facility. The prediction of the angle of attack correction in both test sections is based on the representation of the model by lifting lines and the solution of the wall interference problem by the finite difference method. The value of the porosity factor ascribed to the test section with perforated walls is checked by comparing the measured wall pressure distributions with the computed ones. The lift interference effects on the models M1 and M3, having the wing span to wind tunnel width ratios of 0.19 and 0.31 respectively, were found within the limits of experimental errors. For model M5, having a wing span to wind tunnel width ratio of 0.65, the solid and perforated test section measurements corrected for a uniform angle of attack correction show good agreement up to the lift coefficients of about 0.5. At higher values of the lift coefficient, the effects of the spanwise variation of the angle of attack correction in the solid wall test section become significant.

HIGH REYNOLDS NUMBER SUBSONIC FLOW SEPARATION

Model design and traversing probe designs are complete, and construction of components well underway. A pilot version of the dual pitot/hot wire probe head has been checked out in the NAE 8-in. pipe. Calibration of obstacle blocks, used to measure skin friction, is being carried out in the 8-in. pipe.

REYNOLDS NUMBER EFFECTS ON TWO-DIMENSIONAL AEROFOILS WITH MECHANICAL HIGH LIFT DEVICES

A multicomponent airfoil model, based on a supercritical airfoil, is being designed. The model will be equipped for pressure measurements on all components and provision is also made for boundary layer — wake surveys in the vicinity of the airfoil surface. The model is part of a program aimed at a detailed analysis of 2-D high lift flow and the effect of Reynolds number on the optimum flap settings.

Work on an iterative solution of the compressible boundary layer flows about multi-element airfoils is continuing at the University of Manitoba.

TESTS IN THE 5-FT. × 5-FT. BLOWDOWN TUNNEL FOR OUTSIDE ORGANIZATIONS

SAAB-Scania, Sweden

A program of tests on a typically modern, high technology transport aircraft model was completed. Extensive pressure measurements were made in addition to overall forces and moments.

Space Research Corporation

An investigation of the shock swallowing and expulsion characteristics of a family of annular intakes was completed.

Canadair Limited, Montreal

A preliminary investigation of a 1/25 scale model of the CL-600 Learstar aircraft has been completed. The tests were limited to force and moment measurements made on configurations involving different wing designs and engine nacelle locations. Visualizations of the flow in the nacelle/pylon/fuselage function and other regions of interest were also made.

This preliminary model was tested with empennage; a second model with an empennage is to be tested in the near future. Design of the special sting required for this test is underway.

HYDRAULICS LABORATORY

ST.LAWRENCE SHIP CHANNEL

Under the sponsorship of the Ministry of Transport, a study to improve navigation along the St.Lawrence River, using hydraulic and numerical modeling techniques.

NUMERICAL SIMULATION OF RIVER AND ESTUARY SYSTEMS

Mathematical models have been developed to simulate tidal propagation in estuaries, wave refraction in shallow water and littoral drift processes.

DEVELOPMENT OF SPECTRAL ANALYSIS PROGRAMS

For use in the analysis of wave records and on-line analysis of turbulent diffusion data produced in the laboratory.

WAVE FORCES ON OFF-SHORE STRUCTURES

Wave flume study to determine design criteria for off-shore mooring structures.

RANDOM WAVE GENERATION

A study of random waves generated in a laboratory water wave flume by signals from a computer.

CHURCHILL HARBOUR MODEL STUDY

A hydraulic model study to determine effects of extending wharf facilities at Churchill, Man. on local flow pattern and the effect of diversion of upland discharge on salinity distribution is estuary. The model study has been completed and a report will be issued to the National Harbours Board early in 1977.

MIRAMICHI CHANNEL STUDY

A hydraulic model study to determine the feasibility of deepening the navigation channel of the Miramichi River, N.B. While the hydraulic model study has been completed, a mathematical model is being used to calculate the transport capacities of the upstream section of the estuary. A final report will be available in 1977.

LOCK MODEL STUDY ON VESSEL SIZE

In co-operation with the Marine Dynamics and Ship Laboratory a model study has been undertaken to determine the effect of vessel and lock dimensions on the entrance and exit speeds of ships in locks of the St. Lawrence Seaway.

STABILITY OF RUBBLE MOUND BREAKWATERS

A flume study for the Department of Public Works to determine stability coefficients of armour units and the effect of a number of wave parameters on the stability of rubble mound breakwaters.

WAVE LOADS ON CAISSON TYPE BREAKWATERS

A flume study for the Department of Public Works to determine the overall loading, as well as the pressure distribution on various Caisson-type breakwaters.

WAVE POWER AS AN ENERGY SOURCE

A general study to assess the wave power available around Canada's coast and to evaluate various proposed schemes to extract this energy. International co-operation is taking place through the International Energy Agency of OECD.

LOW SPEED AERODYNAMICS LABORATORY

WIND TUNNEL OPERATIONS

The three major wind tunnels of the Laboratory are: the 15-ft. diameter, open jet, vertical tunnel; the 6-ft. × 9-ft. closed jet, horizontal tunnel; and the 30-ft. V/STOL tunnel. During the quarter, 13 programs were undertaken which included work for Canadair Ltd., DeHavilland Aircraft of Canada Ltd., and the Wind Engineering group of the Laboratory.

WIND ENGINEERING

An investigation, undertaken for Transport Canada in collaboration with the Canada Safety Council, into the stability of highway advance warning devices was completed. The first phase, done in the previous quarter, was to measure the velocity field in which the devices are located alongside a model of a highway tractor trailer in the 6-ft. × 9-ft. wind tunnel. The second phase, done in the 3-ft. × 3-ft. wind tunnel using five commercially available devices, was to establish whether or not they will remain fixed in position and not overturn at the windspeed specified by the Canadian Standards Association. As a result of the first phase of the program a higher standard windspeed will be recommended.

The flutter behaviour and vortex shedding excitation of a 2600 ft. long, six lane cable stayed bridge proposed for the St. Johns River, Jacksonville, Florida was investigated in the 15-ft. vertical tunnel using a 1:60 scale sectional model. Flutter coefficients and static force and moment coefficients were also measured for purposes of further analysis of the bridge response. The work was done for the engineering firm Howard, Needles, Tammen and Bergendoff.

An investigation was made in the 6-ft. × 9-ft. wind tunnel for the Aluminum Company of Canada into the wind loading on three in-line slender alumina digester towers to be built in San Ciprian, Spain. Measurements were made of tower base bending moments and the forces in bracing between the towers that was required to reduce the amplitude of wind-induced motion.

Vortex shedding and galloping response measurements were made in the 3-ft. × 3-ft. wind tunnel for the 550-ft. high flare stack tower at the La Prade heavy water plant now under construction. A 1:32 scale dynamically mounted model was used. The tests were done for CANATOM-MHG.

Surface pressure measurements on a variety of building configurations were made in the 6-ft. × 9-ft. wind tunnel as part of a collaborative program with the Division of Building Research on the prediction of air infiltration.

The Laboratory has been involved in an advisory capacity in a program of road measurements of the effectiveness of drag reduction devices for full scale trucks and tractor-trailers which has been undertaken under the auspices of the Transportation Development Agency and the Department of Energy Mines and Resources. This program complements earlier wind tunnel investigations in the Laboratory. Preliminary analysis of the full scale results indicate agreement with trends predicted by the model scale measurements.

The Laboratory has undertaken an investigation for the Olympic Installation Board into the aerodynamics of the proposed removable portion of the roof, of the Olympic Stadium. Cable forces at the roof attachment points are to be measured.

FLUIDICS

Co-operative studies with D.G. Instruments of a 3-axis air velocity sensor are continuing using both NRC and industry developed concepts. Studies of vortex excitation of velocity sensor probes

have been carried out in co-operation with FluiDynamic Devices Ltd. A program of applications of laminar flow in thin passages is being carried out in co-operation with the Control Systems and Human Engineering Laboratory of DME.

NUMERICAL METHODS

A correlational theory for the prediction of boundary layer transition has been devised and successfully demonstrated in some simple cases which are of interest for the design of airfoils.

The numerical methods are applicable to compressible flows involving heat and mass transfers at the boundaries.

VERTICAL AXIS WIND TURBINE

Dominion Aluminum Fabricating Ltd. has delivered six 15-ft. diameter wind turbines to NRC, who in turn has shipped these units to interested federal agencies for field trials. These units are now in operation. DAF are now marketing two sizes (a 15-ft. diameter (4kW) and a 20-ft. diameter (6kW) turbine). Erection of the 200kW demonstration unit is proceeding at the Magdalen Islands site.

AERIAL SPRAYING OF PESTICIDES

A co-operative program between NAE and the University of New Brunswick, to determine the droplet size distribution of standard nozzle configurations, has been completed. The experimental method consisted of photographing droplets in the 50- to 250-micron range using a narrow depth of focus, and a high intensity flash. An electronic detector was also placed in the spray; its function was to count the number of droplets in a given size range. The second stage of the experiment has been completed with measurements of droplet emissions from a Micronair rotary atomizer being made.

A new spray boom design has been tested in co-operation with Conair Aviation (Abbotsford, B.C.). This configuration will have significantly less aerodynamic drag than the present installation which is used on the DC-6B aircraft and is expected to save several hundred horsepower.

Theoretical and experimental studies are continuing on the effects of the vortex wake and other factors on the swath width of spray left by a low flying aircraft.

LOW TEMPERATURE LABORATORY

RAILWAY CLIMATIC PROBLEMS

Under the auspices of the NRC Associate Committee on Railway Problems, Sub-Committee on Climatic Problems, a variety of analytical and experimental work is conducted on a continuing basis.

THERMAL PROTECTION OF TRACK SWITCHES

The use of heat to eliminate switch failures from snow and ice is a standard approach to this problem. Work has been carried out on improving the efficiency of forced convection combustion heaters and the means of distributing heat to the critical areas of a switch.

HORIZONTAL AIR CURTAIN SWITCH PROTECTOR

A non-thermal method of protecting a switch from failure due to snow has been undergoing development and evaluation. This method consists of high velocity horizontal air curtains designed to prevent the deposit of snow in critical areas of a switch. The tests conducted to date are especially encouraging with respect to yards and terminals. Additional evaluation is required for the line serivce application.

NEW RAILWAY SWITCH DEVELOPMENT

The ultimate solution to the existing problem of snow and ice failure of the point switch would appear to be replacement by a new design that is not subject to failure in this way. A switch has been designed, fabricated, laboratory tested and has now completed one winter season of field trials. The design involves only shear loading from snow and ice.

LOCOMOTIVE SANDING EQUIPMENT

An investigation into the various possible modes of failure of a locomotive sanding system resulting from low temperature has been undertaken. In addition to the expected failures resulting from moisture freezing in various parts of the pneumatic equipment, two other modes of failure are being investigated further.

HELICOPTER DE-ICING

A study of helicopter icing protection involving the evaluation of various systems (thermal, fluid, and self-shedding materials) and the development of de-icing control systems including ice detectors. The principles for a dynamic ice detector with high sensitivity to be used on helicopters are being investigated. Investigation of methods of establishing a rate function with the dynamic icing detection principle is being conducted.

MISCELLANEOUS ICING INVESTIGATIONS

Analytical and experimental investigations of a non-routine nature, and the investigation of certain aspects of icing simulation and measurement.

TRAWLER ICING

In collaboration with Department of Transport, an investigation of the icing of fishing trawlers and other vessels under conditions of freezing sea spray, and of methods of combatting the problem.

AIR CUSHION VEHICLE ENVIRONMENTAL PROBLEMS

A study has been started on the deposition of snow on sections representing possible tracks for guided ACV's. Snow and ice deposits are being measured and recorded during each winter storm.

A study of snow removal by unconventional methods is being undertaken for high speed transit systems.

AIRBORNE SNOW CONCENTRATION

To provide statistical data on the airborne mass concentration of falling snow in order to define suitable design and qualification criteria for flight through snow, measurements of concentration and related meteorological parameters are being made.

SEA ICE DYNAMICS

Analytical and experimental work on the techniques of forming low-strength ice from saline solutions is being carried out in connection with proposed modelling studies of icebreaking ships and arctic port facilities.

MARINE DYNAMICS AND SHIP LABORATORY

HIGH SPEED CRAFT

Several models in a systematic series have been studied and others are being prepared to determine their performance in still water and in waves.

YACHTS

A program of sailing yacht model studies is underway using equipment and techniques developed in the laboratory.

BULK CARRIER

A model of a dry cargo vessel was constructed in the laboratory and a careful investigation made to determine the feasibility of its unique design.

FOIL PROGRAM

An experiment program is to be conducted on a model of a hydrofoil main foil, for which program a special dynamometer has been built by the laboratory.

HYDROFOIL DESIGN SERIES

A series of five hydrofoil models is being considered and two have been built for investigation of their hull lift and drag, foil lift and drag seakeeping.

BEHAVIOUR OF SHIPS IN LOCKS

Three radio-controlled Great Lakes cargo vessel models with varying length beam ratios have been built in the laboratory. A study of their behaviour is being carried out in a Seaway lock model in co-operation with the Hydraulics Laboratory. Investigation is being made of the hydrodynamic forces acting on the vessels during approach and passage through the locks with a view to recommending modifications to the existing lock structures.

OIL DRILLING PLATFORM

Studies on a model are being made to determine towing forces, joint loading and rotation over a range of wave lengths, speeds, and ballast conditions both in still water and in waves.

BULB NOZZLE

A model of a bulb nozzle is being built in the laboratory for the purpose of determining its effectiveness independent of the ship's hull.

Y-PASS SYSTEM

A model equipped with a Y-Pass system is to be manufactured in the laboratory and its performance evaluated.

RAILWAY LABORATORY

RAILWAY STUDIES

The laser system developed for measuring angle of attack of the axle to the track is now in use by CP Rail.

Further tests on the grain car loaned by the Canadian Government have been delayed and will be continued during 1977.

Rebuilding of the dynamometer car supplied by CP Rail for use as a mobile instrument car has been delayed.

Two experimental axles with spin controlled geometric properties are being manufactured for testing at the Uplands Test Site.

Design and development continues on a transducer to measure surface movement of wheel over rail during rolling.

Preliminary design work has commenced on the measurement of rail-wheel forces using capacitive sensors on the rail.

RAILWAY DYNAMICS BUILDING (U-89)

The installation of support beams in the floor of the building is nearing completion. Design of an acoustically insulated control room, rail supports, vibration stands and associated structures to be incorporated in the building are nearly complete.

Rooms and services are being constructed for the provision of electrical power to the roller rig and a small machine shop.

Development of the control systems for motor drives and roller stand positioning continued with the assistance of a hybrid computer model developed in conjunction with the Analysis Laboratory.

Hardware for the roller rig is being developed and made by the Manufacturing Technology Centre.

GENERAL INSTRUMENTATION

The laboratory is co-operating with the Marine Dynamics and Ship Laboratory in the development of the micro-processor controlled ship motion analyzer.

MECHANICAL AIDS TO THE HANDICAPPED

A pocketbook page turner has been developed; one model has been evaluated in the Ottawa Children's Hospital and is now at the Markham Participation House for evaluation by older children and young adults.

NON-CONTACTING LEVEL GAUGE

Development of a non-contacting servo gauge using stepping motor drive for the measurement of tidal levels in hydraulic models.

AERONAUTICAL AND MECHANICAL ENGINEERING LIBRARY

MEDICAL AIDS TO SURGERY

Continued technical support to two local hospitals in the use of prototype and commercial vessel suturing instruments for clinical surgery, and to their Departments of Experimental Surgery in organ transplant procedures, arterio-venous surgery, etc.

A new form of driving mechanism devised to give reduced actuating forces on the larger sizes of vessel suturing instruments has been proven effective in surgery.

Assistance to Control Systems and Human Engineering Laboratory in the manufacturing of electrodes to improve the recording of electrospinograms.

ASSISTANCE TO HEALTH AND WELFARE CANADA, MEDICAL SERVICES BRANCH

Construction of a device for cutting human hair into centimeter length bundles for mercury analysis.

STRUCTURES AND MATERIALS LABORATORY

FATIGUE OF METALS

Studies of the basic fatigue characteristics of materials under constant and variable amplitude loading; fatigue tests on components to obtain basic design data; fatigue tests on components for validation of design; studies of the statistics of fatigue failures; development of techniques to simulate service fatigue loading.

RESPONSE OF STRUCTURES TO HIGH INTENSITY NOISE

Study of excitation and structure response mechanisms; study of panel damping characteristics and critical response modes; investigation of fatigue damage laws; industrial hardware evaluation; investigation of jet exhaust noise.

OPERATIONAL LOADS AND LIFE OF AIRCRAFT STRUCTURES

Instrumentation of aircraft for the measurement of flight loads and accelerations; fatigue life monitoring and analysis of load and acceleration spectra; full-scale fatigue spectrum testing of airframes and components.

ELECTRON FRACTOGRAPHY

Qualitative determination of fracture mechanisms in service failures; fractographic studies of fatigue crack propagation rates and modes.

METALLIC MATERIALS

Structure-property relationships in cast and wrought nickel-base superalloys. Studies of the consolidation and TMT processing of superalloy powders and compacts by hot isostatic pressing, hot extrusion and upset forging; studies on mechanical properties. Mechanics of cold isostatic compaction of metal powders, properties of hydrostatically extruded solids and compacts, extruded at pressures up to 1600 MN/m^2. Studies of the oxidation/hot corrosion behaviour of coated and uncoated refractory metals and superalloys.

MECHANICS AND THEORY OF STRUCTURES

Stresses in multi-cell caissons for marine structures. Stress concentrations at corners of box structures. Behaviour of plates under high-speed impact, with reference to bird resistance of aircraft windshields.

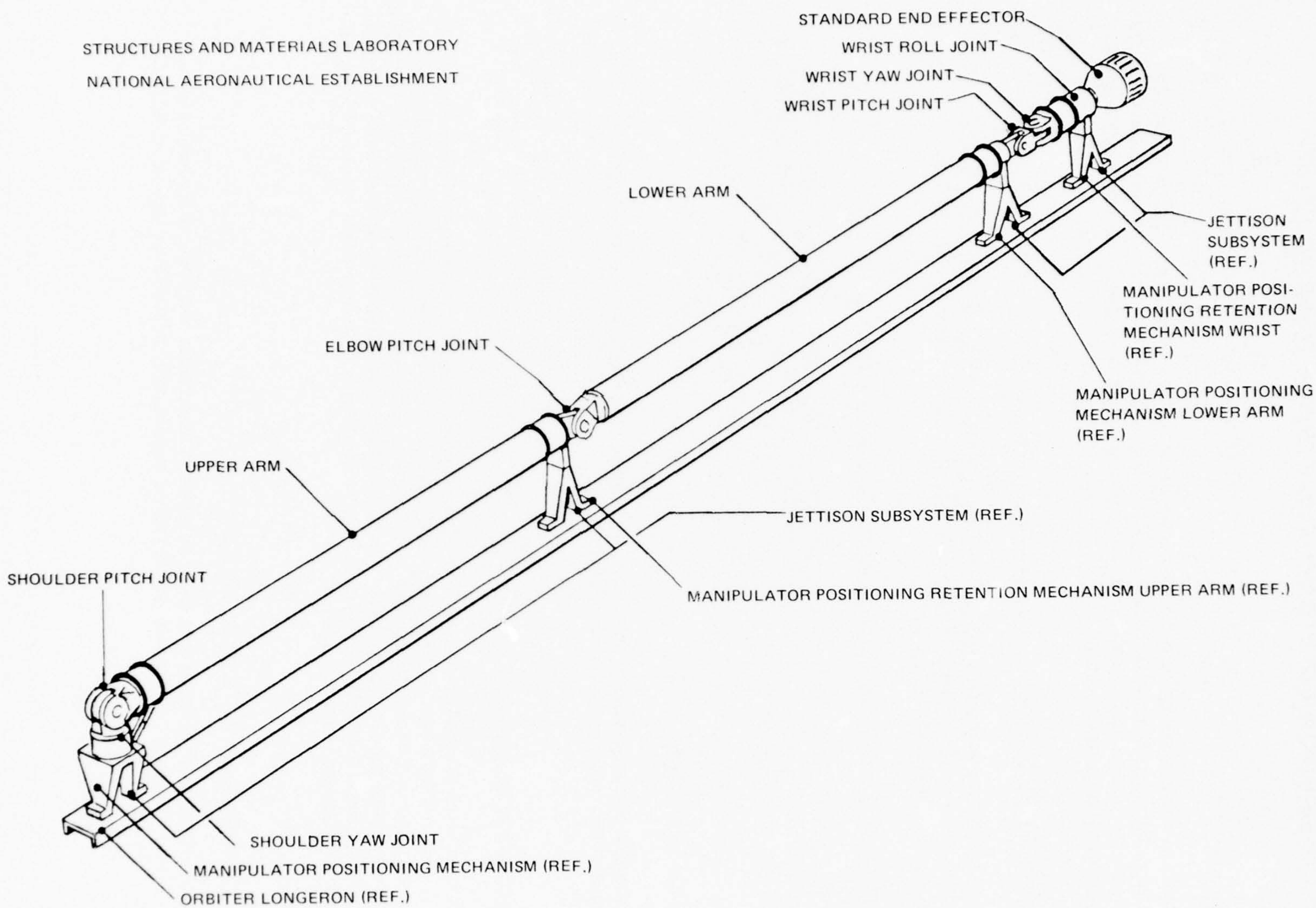
FLIGHT IMPACT SIMULATOR

Simulator developed and calibrated to capability of accelerating a 4-lb. mass to velocity of 1000 ft/sec and an 8-lb. mass to velocity of 760 ft/sec; operation on year-round basis achieved and includes use of temperature controlled enclosure from $-40°$ to $+130°F$; in addition to airworthiness certification program includes assessment of resistance to impact for materials and structural design for most types of viewing transparencies.

PROPRIETARY PROJECTS DURING 1976

STRUCTURES AND MATERIALS LABORATORY

NATIONAL AERONAUTICAL ESTABLISHMENT



REMOTE MANIPULATOR SYSTEM LINE DRAWING.

A CO-OPERATIVE PROGRAM BETWEEN CANADA (NRCC) AND THE U.S.A. (NASA)

CALIBRATION OF FORCE AND VIBRATION MEASURING DEVICES

Facilities available for the calibration of government, university, and industrial equipment include deadweight force standards up to 100,000 lb., dynamic calibration of vibration pick-ups in the frequency range 10 Hz to 2000 Hz.

COMPOSITE MATERIALS

Studies of composites including resins, crosslinking compounds, polymerization initiators, selection of matrices and reinforcements, application and fabrication procedures, material properties, and structural design.

FINITE ELEMENT METHODS

Development and application of finite element methods to structural problems. Development of refined elements with curved edges. Development of methods for non-linear problems.

MOTOR VEHICLE SAFETY

The mathematical model of the redirection of a vehicle by a cable barrier has been validated experimentally and effort is now being concentrated on the development of a facility for the dynamic measurement of the inertial properties of automobiles by suspending them on air bearings. Engineering charts for the design of flexible road barriers are being prepared.

In collaboration with Ministry of Transport, Road and Motor Vehicle Traffic Safety Branch, studies to determine the performance of headlights in the driver passing task are being carried out. Work is continuing on a system for studying driver performance and traffic quality by the analysis of automatically recorded vehicle control input and response data.

POLICE EQUIPMENT STANDARDS

The NRC/CACP Technical Liaison Committee on Police Equipment is a bilateral arrangement for bringing together police and government personnel to review police equipment requirements, equipment performance specifications, and conformance testing procedures. Work of the Committee is expedited by a permanent Secretariat which has a primary responsibility for continuity in the activities of a number of Sections, each dealing with a particular area of expertise, and for co-ordinating work and specialist contributions from various participating Departments and organizations.

UNSTEADY AERODYNAMICS LABORATORY

DYNAMIC STABILITY OF AIRCRAFT

Development of new techniques for dynamic stability experiments.

Determination of cross-derivatives on an aircraft-like configuration at high angles of attack.

Exploratory measurements of vertical acceleration derivatives at transonic and supersonic speeds.

Development of an electro-mechanical calibrator for the existing dynamic cross-derivative apparatus.

ATMOSPHERIC DISTRIBUTION OF POLLUTANTS

Analysis of the downwind vertical spread of gaseous and aerosol pollutants from sources near the ground, with special emphasis on the effect of atmospheric stability.

Instrumentation of a small mobile laboratory for measurements of the concentration and particle size of airborne pollutants.

Application of the above detection system to experiments designed to assess the reliability of analytical methods of dispersion prediction.

TRACE VAPOUR DETECTION

Development of highly sensitive gas chromatographic techniques for detection of trace quantities of vapours of pesticides, explosives and fluorocarbons.

Sensitivity evaluation of commercially available explosive detectors.

Airborne and ground-vehicle based measurements of the spread and distribution of various aerosols and tracer gases.

WORK FOR OUTSIDE ORGANIZATIONS

Dynamic moment measurements and flow visualization studies for NASA, using wind tunnel facilities at NAE and at NASA Ames.

Feasibility and design studies for NASA.

Aircraft-security feasibility studies for Transport Canada.

Scientific assistance to interdepartmental Explosives Detector Evaluation Program, Montreal.

WESTERN LABORATORY (VANCOUVER)

PRACTICAL FRICTION AND WEAR STUDIES

Laboratory simulations of practical sliding contact and bearing conditions to obtain the friction and wear characteristics of lubricants and materials in response to specific requests from industry and other organizations. These have recently included:

Measurement of the relative erosion resistance of cast irons used in a rock/sand feeder for a pneumatic conveying system.

High temperature friction and wear testing of materials for a gas turbine stator pivot bearings.

Measurement of friction between cast iron buttons and bronze clutch plates to assess the effect of plate wear and plate material variations on the effectiveness of a hydraulic clutch.

FUNDAMENTAL STUDIES IN TRIBOLOGY

Continuing investigations of friction and wear processes in general including formulation of a new project to study aspects of the friction and wear behaviour of non-metallic materials.

LUBRICANT ANALYSIS

Analysis of used marine oils to assess their degree of deterioration as an aid to the prevention of engine failures.

PRACTICAL STUDIES OF BEARINGS AND SEALS

Design of a machine to test the effectiveness of the lubrication system of locomotive traction motor support (journal) bearings at low temperatures.

Design of a static model of a vane in a ship's hydraulic steering gear to assess the effect of changes in seal materials and design on leakage.

INSTRUMENTATION STUDIES

Continued development of a photoelectric automatic bus passenger counting system, in particular the utilization of a distributed light source.

The numerical control (N.C.) editor program, NCEDIT, (Report LTR-IN-300 has been modified and expanded. Testing has been completed and the new version is now in use in the Vancouver Laboratory. Documentation is in progress.

A memory protect function has been constructed and added to the Vancouver Laboratory mini computer system and a semi-conductor memory expansion is in design.

Instrumentation has been developed for the Division of Building Research for the automatic tape recording of velocity and pressure measurements in snow avalanches in the Rogers Pass near the Trans-Canada Highway.

NUMERICALLY CONTROLLED MACHINING

Technical assistance on this subject is being provided to firms and other institutions in Western Canada which are considering the purchase of numerically controlled machines to improve their production efficiency. Seminars are held to explain the fundamentals of numerical control and programming and the laboratory's three axis NC milling machine is used to machine demonstration batch quantities of typical components for interested companies.

PUBLICATIONS

1976 ICAS PROCEEDINGS

The 10th CONGRESS of the INTERNATIONAL COUNCIL of the AERONAUTICAL SCIENCES

held in Ottawa, October 4 - 8, 1976

The Proceedings of the 10th Congress of ICAS, containing 56 papers (650 pages), are available upon request to:

Miss S.B. Angel, Publications,
National Research Council of Canada,
NAE, Bldg. M-16, Room 204,
Montreal Road,
OTTAWA, Ontario
K1A 0R6

These Proceedings will be mailed upon receipt of cheque, made payable to the Receiver General of Canada, for $25.00 in Canadian funds.

FOURTH TURBO MECHANICS SEMINAR

ASSOCIATE COMMITTEE ON PROPULSION
TURBO MECHANICS SUB-COMMITTEE

held in Ottawa, September 1976

The Proceedings of the Fourth Turbo Mechanics Seminar, containing two papers (50 pages) are available upon request to:

W. Grabe, Secretary,
Associate Committee on Propulsion,
Turbo Mechanics Sub-Committee,
National Research Council of Canada,
Montreal Road, Bldg. M-7,
OTTAWA, Ont.
K1A 0R6

COST: $2.00

The following unclassified reports were released during the quarter.

MECHANICAL ENGINEERING REPORTS

ME-244 CENTRIFUGAL BLOWER NOISE STUDIES: LITERATURE SURVEY AND NOISE MEASUREMENTS.

G. Krishnappa, Division of Mechanical Engineering, December 1976.

A review of the existing literature on the subject of centrifugal fan and blower noise studies is presented in this report, to establish further areas of research needed to aid in the development of a quiet blower. Noise measurements on a wide variety of blowers used in the laboratory, ranging from 1/3 to 700 horsepower are described with an object of identifying important frequency components from various types of blowers.

The existing literature suggests that the blade passing frequency tone and its harmonics are produced by the interaction of the flow issuing from the blade exit with the cut off edge formed by the junction of the blower casing and its exhaust duct and the random noise is generated by the unsteady flow processes within the impeller. The blower casing and ducted environment is shown to exert a powerful influence on noise characteristics. Among the various blowers tested, the prominent noise component appeared to be the tone at the blade passing frequency.

MP-71 PRODUCTION OF A HYDROCARBON-TYPE SYNTHETIC FUEL FROM WOOD.

L. Gardner, Division of Mechanical Engineering, September 1976.

As the world petroleum reserves become depleted considerable attention is being focussed on alternate sources of energy. In the short term, at least, the synthesis of hydrocarbon fuels similar in composition to present petroleum based fuels is the preferred choice for automotive use. Synthetic fuels of this type can be produced from coal, however the possibility of producing a similar fuel from wood has not been considered to any extent. A theoretical study of the production of fuels from wood via pyrolysis and the Fischer-Tropsch synthesis has therefore been made. The results of this study, as presented in this report, indicate that although technically feasible the production of such a fuel is financially and energy-wise uneconomical.

LABORATORY TECHNICAL REPORTS

National Aeronautical Establishment

LTR-FR-55 Daw, D.F.

The N.A.E. Meteorological Tower.
September 1976.

LTR-LA-205 Irwin, H.P.A.H.

Sectional Model Experiments on Lions' Gate Bridge, Vancouver.
December 1976.

LTR-UA-38 Orlik-Rückemann, K.J., Hanff, E.S. and LaBerge, J.G.

Direct and Cross-Coupling Subsonic Moment Derivatives Due to Oscillatory Pitching and Yawing of an Aircraft-Like Model at Angles of Attack Up to 40° in Ames' 6′ × 6′ Wind Tunnel.
November 1976.

LABORATORY TECHNICAL REPORTS (Cont'd)

National Aeronautical Establishment (Cont'd)

LTR-UA-39	Hanff, E.S. Three-Degrees-of-Freedom Dynamic Calibrator for Oscillatory Cross-Derivative Apparatuses. November 1976.
LTR-UA-40	Anstey, C.R. and Hanff, E.S. Development of a Hydraulic Drive for a 2.5 Inch Diameter High-Load Oscillatory Pitching Apparatus. November 1976.

Division of Mechanical Engineering

LTR-CS-161	Schwartz, J.-L. and Male, R. The Effect of a High Intensity Magnetic Field on the Conduction Velocity of the Circumesophageal Nerve of the Lobster. November 1976.
LTR-ENG-51	Schaub, U.W., Dobrodzicki, G.A. Some Flow Visualization Tests of an Automotive Cooling Fan Blade in the National Aeronautical Establishment Water Tunnel. August 1976.
LTR-ENG-52	Lowe, I.R.G., Dudgeon, E.H. Verification of Two Air Flow Measuring Devices. October 1976.
LTR-FL-91	Friend, M.J. and Davidson, D.M. Development of an Alternative High Torque Test Procedure for Automotive Gear Oils. September 1976.
LTR-FL-94	Dayson, C. and Lowe, J.T. Laboratory Erosive Wear Tests on Three Cast Irons. November 1976.
LTR-GD-45	Brierley, W.H. and Vijay, M.M. Rotating High Pressure Water Jet Gooseneck Cleaner. November 1976.
LTR-HY-55	Funke, E.R. and Haines, S.A. A Force Balance for the Measurement of Shear Forces on Marine Deposits. September 1976.

LABORATORY TECHNICAL REPORTS (Cont'd)

Division of Mechanical Engineering (Cont'd)

LTR-HY-57 — Mogridge, G.R. and Jamieson, W.W.

A Design Method for the Estimation of Wave Loads on Square Caissons.
October 1976.

LTR-SH-184 — Murdey, D.C. and Killing, S.

A Procedure for Testing Sailing Yachts.
February 1976.

LTR-SH-192 — Miles, M. and Murdey, D.C.

Results of Measurements of Beach Reflection Coefficients for Two Beaches Fitted in the NRC Ship Tank.
April 1976.

LTR-SH-193 — Gospodnetic, D.

Texas Instruments 980A Computer System with Floating Point Hardware.
May 1976.

LTR-SH-194 — Gospodnetic, D.

Optimization of Function Subroutines for the TI980A Fortran Library.
August 1976.

TECHNICAL TRANSLATION

TT-1890 — SUPERPLASTICITY OF HIGH-TEMPERATURE NICKEL-BASE SUPER-
* $3.96 — ALLOYS MADE BY POWDER-METTALURGY

THYSSEN TECHNISCHE BERICHTE, 6(1): 53-58, 1974

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* The above translation is available from the Translation Section, NRC Library, Sussex Drive, Ottawa, Ontario, either on an exchange basis with libraries of Government departments and universities or at the price indicated.

MISCELLANEOUS PAPERS

Anstey, C.R. A Compact Four-Component Control-Surface Balance. Presented at the 46th meeting of the Supersonic Tunnel Association, Columbus, Ohio, 30 Sept. - 1 Oct. 1976. Also LM-UA-180.

Buck, L. Psychomotor Test Performance and Sleep Patterns of Aircrew Flying Transmeridional Routes. Published in Aviation, Space and Environmental Medicine, 47(9), 1976, pp. 979-986.

Drummond, A.M. A Comparative Aerial Spray Trail of a Regular and a Small Holed Boom. NAE Lab Memo. FR-79, 18 Oct. 1976.

Elfstrom, G. Turbulent Boundary Layer Separation at High Subsonic Speeds — An Experimental Study. Seminar at Carleton University on November 26, 1976.

Fowler, H.S. The Multicell Skirt. CASPAR A.C.V. Research Project Report No. 4, Program 1. NRC Associate Committee on Air Cushion Technology, October 1976.

Fowler, H.S. Progress Report on Air Cushion Technology in Canada 1975/76. CASI 10th Canadian Symposium on Air Cushion Technology, Calgary 1976. (To be published in Proceedings.)

Fowler, H.S. The Future of Air Cushion Assist in Canada. CASI 10th Canadian Symposium on Air Cushion Technology, Calgary, 1976. (To be published in Proceedings.)

Gospodnetic, D. Floating Point Hardware on TI980A. Texas Instruments Users' Conference "TI MIX IV", Houston, Texas, April 7, 1976.

Heath, J.B.R. and Bosik, A.J. Bird Impact Test Program for Windshields of Small, Light Aircraft. Paper presented at the Conference on Aerospace Transparent Materials and Enclosures, Atlanta, Georgia, 18-21 November 1975. Published April 1976, Technical Report AFML-TR-76-54, pp. 851-885. (Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio 45433.)

Isaac, G.A.*, MacPherson, J.I., MacHattie, L.B.** Cumulus Cloud Seeding for Forest Fire Control — Preliminary Seeding Experiments. Presented at Tenth Congress of the Can. Met. Society, Laval Univ., Quebec City, May 26-28, 1976.

Kekez, M.M. and Savic, P. Laboratory Simulation of the Stepped Leader in Lightning. Can. Journal of Phys., Vol. 54, No. 22, 1976.

Kind, R.J.***, Wardlaw, R.L. Design of Rooftops Against Gravel Blow-Off. National Research Council Canada, NRC No. 15566, Sept. 1976.

Krishnappa, G. Fan Aeroacoustics: The Effect of Stator Blade Number and Spacing on In-Duct Noise Signatures. Aeroacoustics, Progress in Astronautics and Aeronautics Vol. 44, 1976.

Tanney, J.W., Tucker, H.G. and Hayes, W.F. The Evolution of Some Fluid Measurement and Control Components. Published in Automatica, Vol. 12, pp. 343-357, Pergamon Press 1976, printed in Great Britain.

Wood, A.D. Operational Problems in Aviation and their Interaction with Research. Presented at Symposium on Operational Problems, Bangalore India, Oct. 1976. NAE Misc Report 53.

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* Atmospheric Environment Service.
** Canadian Forestry Service.
*** Carleton University.

UNPUBLISHED PAPERS

Adams, P.A. Calibration of Load Cells & Accelerometers. Lecture to SESA Workshop, Toronto. October 19-20, 1976.

Ayad, A.A. The NAE/NRC Headlight Study Program: A Review from 1973 to 1976. Lecture presented to Transport Canada, Highway Safety Group, Ottawa, January 5, 1977.

Chan, A. Some Insight Into Linear Programming Analysis Lab. Seminar, 15 December 1976.

Gellie, R.W. Standards for Industrial Process Control. Presented at ISA/CIM metting in Vancouver, B.C., October 13-15, 1976.

Lowe, I.R.G., Dudgeon, E.H. Flow Modelling Techniques Applied to Combustion in Large Industrial Furnaces. Proc. Symposium on Internal Flows, National Research Council Canada, Associate Committee on Propulsion, Ottawa, 29 October 1976.

Orlik-Rückemann, K.J. NASA/NAE Joint Program on Determination of Damping and Cross Derivatives at High Angles of Attack. Presented at the High-Angle-of-Attack Workshop, Wright-Patterson Air Force Base, Ohio, 29 Nov. - 2 Dec. 1976.

Panarella, E. Mechanism of Laser-Induced Gas Ionization. Lecture delivered at U.B.C., Dept. of Physics, Nov. 1976.

South, P. Wind Power. Talk presented to IEE, Ottawa, Nov. 24, 1976.

Strigner, P.L. A Study of Engine Oil and Filter Change Periods and Engine Oil Monitoring for GM 6V-71 Diesel Bus Engines. Engineering Committee, Canadian Urban Transit Association, Ottawa, November 1976.

Templin, R.J. Wind Energy Research in Canada. Talk presented at Atomic Energy Canada Limited, Chalk River, December 1, 1976.

Templin, R.J. Wind Energy. Talk presented at the Symposia on Ontario's Electrical Future, Toronto, November 17, 1976.

Templin, R.J. Potential for Wind Energy in Canada. Talk presented at the Canadian Building Congress on Energy and Buildings, Toronto, October 25, 1976.

Vijay, M.M. and Brierley, W.H. Experimental and Theoretical Investigations on Hydraulic Rock Cutting. Presented at the Joint Petroleum Mechanical Engineering and Pressure Vessels and Piping Conference, Mexico City, Sept. 1976.

Whyte, R.B. Future Automotive Engines and Fuels. Canadian Institute of Energy, Toronto, October 1976.

Whyte, R.B. Contribution of Low Temperature Gear Oils. Symposium on New Trends in Gear Lube Technology NLGI 44th Annual Meeting, Kansas City, October 1976.

Willis, D.H. Hydraulic Modelling of the Miramichi Estuary. Presented to Fredericton Branch of Association of Professional Engineers of New Brunswick, November 25, 1976.

AERONAUTICAL AND MECHANICAL ENGINEERING LIBRARY

Statistical Summary for October 1 — December 31, 1976

Documents accessioned (including duplicates)	2001
Cards added to catalogue	7325
Books received	150
Bound periodicals received	36
Loans to NRC staff (including Periodical circulation and Xerox and Microfiche copies in lieu of loans)	7303
Loans and distribution to outsiders	2728
Total circulation	10031
Information inquiries (quick references)	3891
Literature searches and bibliographies	364

NOTE: The Uplands Library is no longer a sub-branch of the Aero/ME Library. However, all documents for the Uplands Library are indexed and all document catalogue cards produced by the Aeronautical and Mechanical Engineering Library.

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Statistical Summary for October 1 — December 31, 1976

Regular loans made to NRC divisional staff			797
Loans to CISTI and NRC branch libraries			56
Loans to outside NRC:	a. Universities	1	4
	b. Industries	1	
	c. Govt. Depts	2	
Periodical rapid circulation			824
Xeroxed copies supplied in lieu of loans			121
TOTAL LOANS FOR THE QUARTER			1802
Documents accessioned (including duplicates)			437
Cards added to catalogue:	a. Book cat.	1170	2360
	b. Document	1190	
Books received			23
Bound periodicals received			22
Information inquiries (quick reference)			896
Literature searches			194

PROPRIETARY PROJECTS DURING 1976

Part of the work of the two Divisions covers proprietary projects, and, for this reason, has not been reported in these Bulletins.

Following is a list of Industrial Organizations, Government Departments and Universities for whom work was done during 1976.

INDUSTRIAL ORGANIZATIONS

Aero Photo Inc., Ste-Foy, P.Q.

Airborne Gravity & Seismic Services Ltd., Calgary, Alta.

Air Canada Base, International Airport, Dorval, P.Q.

Air Cushion Industries Ltd., Ottawa, Ont.

Airshield, Rudkin-Wiley Corporation, Stratford, Conn.

Albery, Pullerits, Dickson & Associates Ltd., Don Mills, Ont.

Algoma Steel Co., Sault Ste-Marie, Ont.

Aluminum Company of Canada Limited, Montreal, P.Q.

American Society for Testing & Materials, Philadelphia, Pa.

Arctec Canada Ltd., Montreal, P.Q.

Atlantic Bridge Company Limited, Lunenburg, N.S.

Atlas Polar Co., Toronto, Ont.

Aviation Electric Ltd., Montreal, P.Q.

Aviation Electric (Pacific) Ltd., Edmonton, Alta.

Bach-Simpson Ltd., London, Ont.

Baker Materials Engineering Ltd., Vancouver, B.C.

B.C. Hydro, Vancouver, B.C.

Beaver Asphalt Ontario Ltd., Ottawa, Ont.

B.J. Distributing, Montreal, P.Q.

Bohm, Mr. C.,Ottawa, Ont.

Bombardier Ltd., Valcourt, P.Q.

B.P. Oil Limited, Montreal, P.Q.

B.P. Oil Limited, Oakville, Ont.

Bradley, Mr.,Premier's Office, Charlottetown, N.B.

Bristol Aerospace Limited, Winnipeg, Man.

Bristol Gas Corp., Research and Development Div., Newcastle-Upon-Tyne, England

Buckland and Taylor Limited, Vancouver, B.C.

Burnett Resource Surveys Ltd., Burnaby, B.C.

CAE Machinery Ltd., Vancouver, B.C.

Canadair Ltd., Montreal, P.Q.

Canadian Fram Ltd., Chatham, Ont.

Canadian General Electric, Peterborough, Ont.

Canadian Industries Ltd., Montreal, P.Q.

Canadian Institute for Guided Ground Transport, Kingston, Ont.

Canadian Liquid Air, Montreal, P.Q.

Canadian Marconi Ltd., Montreal, P.Q.

Canadian National Railways, Montreal, P.Q.

Canadian Pacific Airlines Ltd., Vancouver, B.C.

Canadian Pacific Railways, Montreal, P.Q.

Canadian Standards Association, Rexdale, Ont.

Canadian Thin Films Ltd., Burnaby, B.C.

Canasphere Ltd., Moose Jaw, Sask.

Canatom MHG, Montreal, P.Q.

Canplan Oceanology Ltd., Halifax, N.S.

Cansteel Corporation, Halifax, N.S.

Capilano Engineering, Vancouver, B.C.

Capital Air Surveys Ltd., Killaloe, Ont.

Cariboo Pulp & Paper Ltd., Quesnel, B.C.

Carson Luggage of Canada Ltd., Ottawa, Ont.

C. & C. Yachts Manufacturing Ltd., Port Credit, Ont.

Chevron Chemical Co., Oakville, Ont.

Chris Tytler Limited, Pembroke, Ont.

Chrysler Canada Ltd., Windsor, Ont.

Ciba-Geigy Canada, Don Mills, Ont.

Collingwood Shipyards, Collingwood, Ont.

Computing Devices of Canada Ltd., Ottawa, Ont.

Conair Aviation Limited, Abbotsford, B.C.

CP Transport, Don Mills, Ont.

Criterion Engineering, Richmond, B.C.

Davis, Eryou and Associates, Consultants, Ottawa, Ont.

DeHavilland Aircraft of Canada Limited, Downsview, Ont.

Deloro Stellite, Belleville, Ont.

DG Instruments Limited, Kanata, Ont.

Digital Electronic Laboratories Ltd., Ottawa, Ont.

Dilawri Motors, Stittsville, Ont.

Dome Petroleum Ltd., Calgary, Alta.

Dominion Aluminum Fabricating Limited, Mississauga, Ont.
Dominion Engineering Works Ltd., Montreal, P.Q.
Domtar Fine Papers Ltd., Cornwall, Ont.
Domtar Limited Research Centre, Senneville, P.Q.
Dow Chemical of Canada Limited, Sarnia, Ont.
Dufresne Piling Co. (1967) Ltd., Ottawa, Ont.

E.B. Eddy Ltd., Fine Paper Division, Ottawa, Ont.
Eldorado Nuclear Ltd., Port Hope, Ont.
Electrolux Canada Ltd., Montreal, P.Q.
Exxon Research & Engrg., Linden, N.J.

Farinon Electric Co., Montreal, P.Q.
Fathom Oceanology Limited, Mississauga, Ont.
Ferritronics Ltd., Richmond Hill, Ont.
Fleet Industries, Fort Erie, Ont.
FluiDynamic Devices Limited, Mississauga, Ont.
Foley, D.A., Kingston, Ont.
Ford Motor Company of Canada Limited, Oakville, Ont.
Foster Wheeler Limited, St. Catharines, Ont.
F.R. Livingstone Ltd., Consultants, Ottawa, Ont.

Gearmatic Ltd., Surrey, B.C.
General Motors of Canada Limited, Oshawa, Ont.
George Kelk Ltd., Downsview, Ont.
German & Milne, Montreal, P.Q.
G.F. Crate Ltd., Consultants, Ottawa, Ont.
Gilbert, Letourneau & Renaud, Quebec City, P.Q.
Groupe Commerce Assurance, Hull, P.Q.
G.T.E. Automatic Electric, Brockville, Ont.
G.T.R. Campbell (International) Ltd., Montreal, P.Q.
Gulf Oil Limited, Toronto, Ont.

Hall Chemical Co., The, Montreal, P.Q.
Hawker Siddeley (Canada) Ltd., Toronto, Ont.
Hermary, Mr., Surrey, B.C.
Hotel Dieu Hospital, Kingston, Ont.
Hoverlift Systems, Ltd., Calgary, Alta.
Hovey and Associates Ltd., Ottawa, Ont.

Howard, Needles, Tammen & Bergendoff, Jacksonville, Fla.

H&S Tool Co., Richmond, B.C.

Hub Oil Co., Calgary, Alta.

Hussman Store Equipment Ltd., Brantford, Ont.

Imperial Oil Enterprises, Dartmouth, N.S.

Imperial Oil Enterprises, Edmonton, Alta.

Imperial Oil Enterprises, Montreal, P.Q.

Imperial Oil Enterprises, Sarnia, Ont.

Imperial Oil Ltd., Toronto, Ont.

Inco Ltd., Industrial Engineering Dept., Copper Cliff, Ont.

Industrial High Pressure Systems, Gravenhurst, Ont.

International Nickel Co. of Canada, Copper Cliff, Ont.

Irvin Industries Limited, Fort Erie, Ont.

Irving Oil Limited, St. John, N.B.

Ivaco Rolling Mills, L'Original, Ont.

James D. Kendall Consultants Ltd., Toronto, Ont.

Jauvin Truck Centre Ltd., Ottawa, Ont.

J.T. Donald & Co., Ltd., Scarborough, Ont.

Kenting Earth Sciences Ltd., Ottawa, Ont.

Klein Engineering Ltd., Ottawa, Ont.

K.L. Philpott, Consulting Engineer, Toronto, Ont.

Landis Realty Ltd., Ottawa, Ont.

La Société de Cartographie de Québec Ltée., Quebec, P.Q.

Leigh Instruments Ltd., Carleton Place, Ont.

Lloyds Registry Shipping, Montreal, P.Q.

Lockwood Survey Corp., Ltd., Vancouver, B.C.

LRC Consortium — MLW Industries, Montreal, P.Q.

LRC Consortium — DOFASCO, Hamilton, Ont.

LRC Consortium — Alcan, Montreal, P.Q.

MacMillan Bloedel, Vancouver, B.C.

Markham Participation House, Markham, Ont.

McDonnell-Douglas, Long Beach, California, U.S.A.

McRostie Genest Middlemiss Associates, Ottawa, Ont.

Mechron Engineering Ltd., Ottawa, Ont.

Meunier, Mr. Rodolf, Gatineau, P.Q.

MLW Industries Ltd., Montreal, P.Q.

Montreal Neurological Institute, Montreal, P.Q.

Motor Oils Company, Lyons, Ill.

Noranda Mines Ltd., Noranda, P.Q.

Nordair, Montreal, P.Q.

Normalair-Garrett Ltd., Yeovil, Somerset, England

Northern Oil, Montreal, P.Q.

Northway Survey Corpo, Edmonton, Alta.

Olympic Installation Board, Montreal, P.Q.

Onex Industries Ltd., Ottawa, Ont.

Ottawa Carleton Transport, Ottawa, Ont.

Ottawa Civic Hospital, Ottawa, Ont.

Ottawa Crippled Children's Treatment Centre, Ottawa, Ont.

Ottawa General Hospital, Ottawa, Ont.

Pacific Survey Corporation, Vancouver, B.C.

Pacific Western Airlines Ltd., Vancouver, B.C.

Petrofina Canada Limited, Pointe-Aux-Trembles, P.Q.

Philips Electronics Industries Limited, Scarborough, Ont.

Photographic Surveys Inc., Montreal, P.Q.

Polar Quick Freezing Co., Summerside, P.E.I.

Port Weller Dry Docks Ltd., St. Catharines, Ont.

PPG Industries Inc., Huntsville, Alabama, U.S.A.

Pratt & Whitney Aircraft of Canada Ltd., Longueuil, P.Q.

Preci Surgical Ltd., Montreal, P.Q.

Procor Corporation, Oakville, Ont.

Quebec Iron & Titanium Co., Sorel, P.Q.

Raflow Devices Limited, Richmond Hill, Ont.

Relevés Aériens Gar-X Ltée., Laval, P.Q.

Renfrew Electric Ltd., Toronto, Ont.

Riverside Hospital, Ottawa, Ont.

R.L. Crain Ltd., Ottawa, Ont.

Rolls-Royce (Canada) Ltd., Lachine, P.Q.

Royal Alexandra Hospital, Edmonton, Alta.

SAAB-Scania, Sweden

Saint John Shipbuilding & Dry Dock Co., Ltd., Saint John, N.B.

S. Albert Company Ltd., Montreal P.Q.

Sander Geophysics Ltd., Ottawa, Ont.

Shell Canada Limited, Pointe-Aux-Trembles, P.Q.

Sidney Steel Co. Ltd., Smelter Div., Sydney, N.S.

Sikorsky Aircraft, Division of United Technologies, Stratford, Conn.

Slater Products (Div. Slater Steel Industries Limited), Hamilton, Ont.

Slingerland, Mr. Alvin, Arnprior, Ont.

Société Nationale Industrielle Aérospatiale, Marignane, France

Space Research Corporation, Montreal, P.Q.

SPAR Aerospace Products Ltd., RMS Design Group, Toronto, Ont.

Stauffer Chemicals, Westport, Conn.

Steel Company of Canada, Hamilton, Ont.

Survair Limited, Ottawa, Ont.

Swan Wooster Engineering Corporation Limited, Vancouver, B.C.

Talbot, Jackson & Associates Ltd., North Vancouver, B.C.

Three Rivers Pulp and Paper Co., Three Rivers, P.Q.

Transair Limited, Winnipeg, Man.

TransCanada Pipelines Ltd., Toronto, Ont.

Transportation Development Agency, Montreal, P.Q.

Tricil Waste Management Ltd., Etobicoke, Ont.

Trident Aircraft, Richmond, B.C.

Turbo Refineries, Edmonton, Alta.

Uniroyal, Don Mills, Ont.

Urban Transportation Development Corp., Toronto, Ont.

Valley Sanitation, Kemptville, Ont.

Victoria Hospital, London, Ont.

Wagner Engineering Ltd., Vancouver, B.C.

Weir's Appraisal Limited, Ottawa, Ont.

Western Peat Moss Ltd., Vancouver, B.C.

Westinghouse Canada Ltd., Hamilton, Ont.

GOVERNMENT DEPARTMENTS AND AGENCIES

Agriculture Canada, Ottawa, Ont.

Alberta Energy & Natural Resources, Edmonton, Alta.

Alberta Transportation, Provincial Government of Alberta, Calgary, Alta.

Atomic Energy of Canada Ltd., Chalk River, Ont.

Atomic Energy Ltd., Toronto, Ont.

Department of Communications, Ottawa, Ont.

Department of Consumer and Corporate Affairs, Calgary, Alta.

Department of Consumer and Corporate Affairs, Edmonton, Alta.

Department of Consumer and Corporate Affairs, Halifax, N.S.

Department of Consumer and Corporate Affairs, Montreal, P.Q.

Department of Consumer and Corporate Affairs, Ottawa, Ont.

Department of Consumer and Corporate Affairs, Toronto, Ont.

Department of Consumer and Corporate Affairs, St. Johns, Nfld.

Department of Economic Growth, Fredericton, N.B.

Department of the Environment, Fredericton, N.B.

Department of Highways, Fredericton, N.B.

Department of Justice, Ottawa, Ont.

Department of Labour, Ottawa, Ont.

Department of Lands and Forests, Quebec City, P.Q.

Department of National Defence, Ottawa, Ont.

Department of National Defence, LaSalle, P.Q.

Department of National Defence, Defence Research Establishment. Valcartier, P.Q.

Department of National Defence, QETE, Hull, P.Q.

Department of Public Works, Ottawa, Ont.

Department of Public Works, Halifax, N.S.

Department of Regional Economic Expansion, Frederiction, N.B.

Department of Regional Economic Expansion, Ottawa, Ont.

Department of Supply and Services, Ottawa, Ont.

Dominion Radio Astrophysical Observatory, Penticton, B.C.

Energy, Mines and Resources Canada, Ottawa, Ont.

Environment Canada, Downsview, Ont.

Environment Canada, Ottawa, Ont.

Federal Aviation Administration, Washington, D.C.

Gloucester Police Department, Gloucester Township, Ottawa, Ont.

Government of Northwest Territories, Frobisher Bay, N.W.T.

Health and Welfare Canada, Medical Services Branch, Ottawa, Ont.

Hydro Quebec, Varennes, P.Q.

Institute of Man and Resources, Charlottetown, P.E.I.

Ministry of Defence, Admiralty Surface Weapons Establishment, Portsdown, Cosham, England.

Ministry of Defence, Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Ministry of Transport, Ottawa, Ont.

Ministry of Transport, Vancouver, B.C.

Montreal Urban Community Police, Montreal, P.Q.

National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Cal.

National Aeronautics and Space Administration, Washington, D.C.

National Capital Commission, Ottawa, Ont.

NRC Associate Committee on Aviation Security, Ottawa, Ont.

Ontario Hydro, Toronto, Ont.

Revenue Canada, Ottawa, Ont.

Royal Canadian Mounted Police, Ottawa, Ont.

St.Lawrence Seaway Authority, St. Lambert, P.Q.

Transportation Development Agency, Ottawa, Ont.

Transportation Development Agency, Montreal, P.Q.

U.S. Army Air Mobility Research and Development Lab., Fort Eustis, Virginia.

U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

U.S. Department of Agriculture, Washington, D.C.

UNIVERSITIES

Algonguin College, Ottawa, Ont.

Carleton University, Ottawa, Ontario.

Concordia University, Montreal, P.Q.

Ecole Polytechnique, L'universite, Montreal, P.Q.

Laval University, Quebec, P.Q.

McMaster University, Hamilton, Ont.

Ottawa University, Ottawa, Ont.

Queen's University, Kingston, Ont.

University of British Columbia, Vancouver, B.C.

University of Florida, Industrial Engineering Department, Gainesville, Florida.

University of New Brunswick, Fredericton, N.B.

University of Toronto, Toronto, Ont.

University of Waterloo, Waterloo, Ont.

University of Western Ontario, London, Ont.

University of West Indies, Electrical Engineering Department, Trinidad, W.I.

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